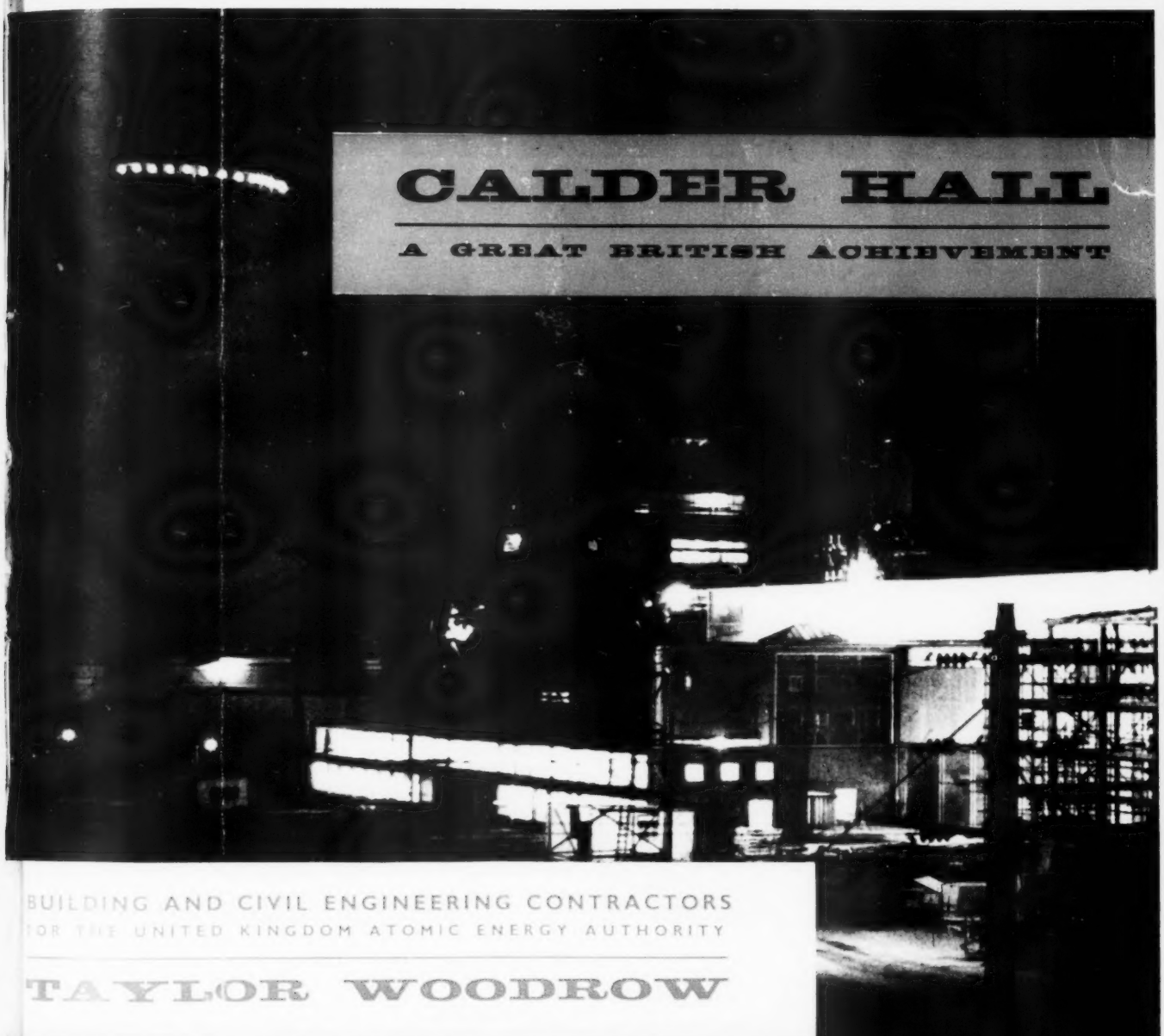
Nuclear Power

The journal of British nuclear engineering

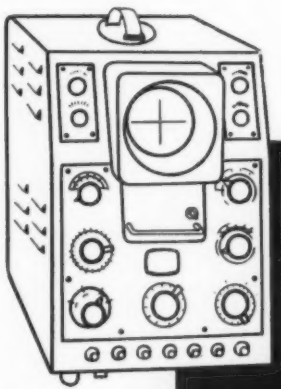


BUILDING AND CIVIL ENGINEERING CONTRACTORS
FOR THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

TAYLOR WOODROW

October 1956 volume I number VI 3s 6d

Cossor Oscillographs in research



The value of the Cathode Ray Oscillograph as an aid to scientific investigation is so high and so widely appreciated that further emphasis on its importance is unnecessary. We *would* emphasise, however, that Cossor Instruments Ltd., in providing a wide range of these invaluable instruments, have been able to help Research with the solution of many of its difficult problems and are anxious to place their long experience of the subject at the disposal of enquirers.

Model 1035 Mk II
Double Beam Oscillograph

Two independent amplifiers with frequency ranges 20 c/s to 7 Mc/s and 20 c/s to 100 Kc/s. The 4-in dia. flat screen tube operates at 2 kV. Time intervals and Input Voltages may be measured on either beam by means of the calibrated controls. Time base for repetitive, triggered or single-stroke scan with velocity 150 milli-seconds to 15 micro-seconds.

The instrument in operation near the face of the British Experimental Pile "BEPO" at the Harwell Research Establishment of the United Kingdom Atomic Energy Authority.

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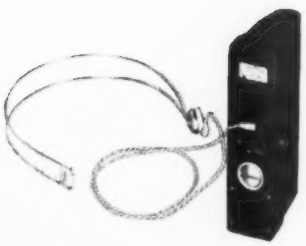
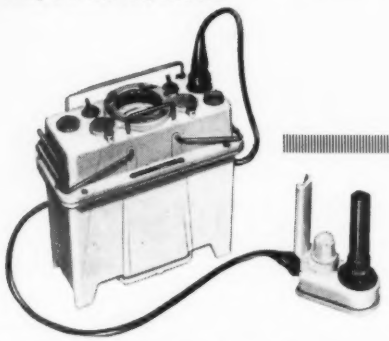
HEALTH INSTRUMENTATION BY PHILIPS

The units illustrated here are selected from Philips range of monitoring equipment designed to safeguard the health of workers in atomic factories and research establishments. Full details will gladly be sent on request.

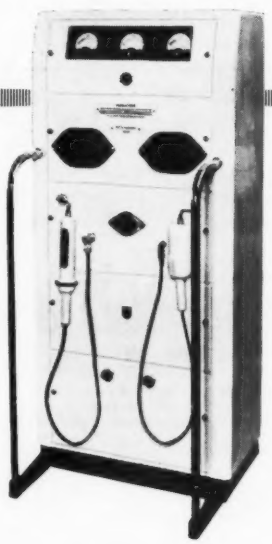
Philips, with their many years' experience in the field of radiation measurement, are best qualified to advise on all health instrumentation problems.



Pocket Battery Monitor type PW 4010. Sensitive to gamma rays, high energy beta radiation and X-rays, with ranges for high and low sensitivity. Low intensities also audibly detectable by earphones. Ideal for intensity measurements in laboratories, checking radio-active sources or tracers, etc. *A product of N.V. Philips, Eindhoven, Holland.*



Contamination Meter type 1092D. Accurately measures gamma activity on clothing, benches, etc. Interchangeable power supply units : high tension battery, mains unit, or vibrator. Cold cathode valves throughout obviate need for filament heating and help to reduce size, weight and maintenance. *Developed in conjunction with U.K.A.E.A., Harwell.*



A number of these monitors have been supplied to Calder Hall

Hand and Clothing Monitor type 1404A. Enables workers to rapidly check their hands and clothing for harmful contamination. The instrument incorporates hand units for detecting beta-gamma radiation and, below these, two frisking probes for checking the clothing for beta-gamma and alpha radiation. Special care has been taken in design to ensure ease of cleaning and quick replacement of contaminated parts. *Developed in conjunction with U.K.A.E.A., Harwell.*

Write or telephone for full details of the complete Philips range of health monitoring equipment.

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RESEARCH AND CONTROL INSTRUMENTS DIVISION

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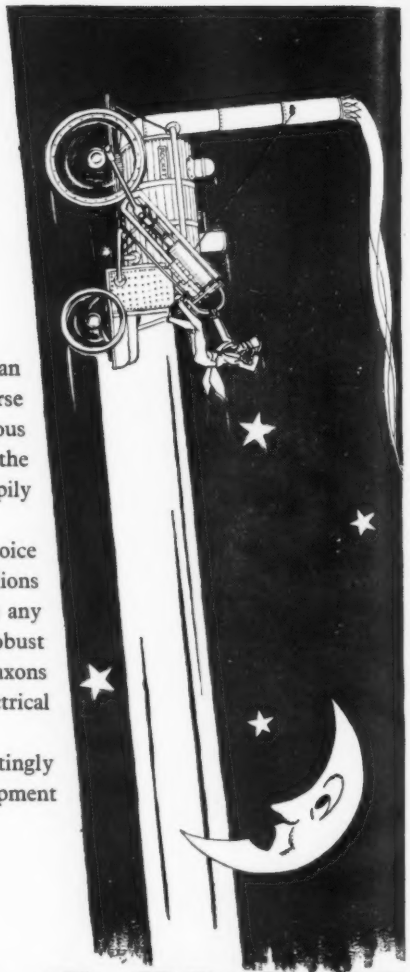
ROCKETS

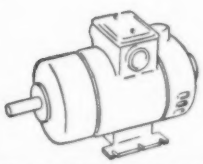
and sky-signs!



We came on the scene in the 'bulb-horn era' — a little later than Stephenson's 'Rocket'. Yet in good time to develop the fractional horse power motors which, with uncanny accuracy, operate the mysterious innards of the 'space' variety. Similar motors, suitably geared, keep the sky signs flashing in Piccadilly and we can supply them to function happily at from 14,000 revolutions per *minute* to one per 24 *hours!*

In 1909 we pioneered the 'Klaxon' Horn which gave raucous voice to Edwardian 'Genevieves' and, more and more melodiously, to millions of other vehicles, ever since. Today, tho' 'Klaxon' means 'horn' in any language, it means a great deal more than that. The sound design, robust construction and faithful workmanship which keep 40 year old Klaxons still a-blowing, are also to be found in a variety of ultra-modern electrical devices.

Delivery is prompt. Our competitors find our prices disconcertingly keen. And we are always willing to conduct research and development with a view to perfecting new devices for special functions.



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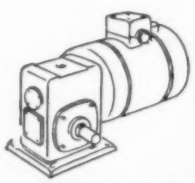
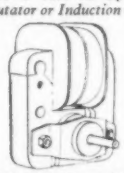
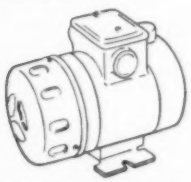


FRACTIONAL HORSE POWER GEARED UNITS
Torques to 2,500 lbs. ins. Speeds down to 1 rev. in 24 hours. Commutator or Induction motors.

FLAMEPROOF HOOTERS
Warning range 200 yds. to 550 yds. 6-250 volts. Suitable for mines, oilfields, etc.



SHADED POLE MOTORS
1/300 h.p. to 1/12 h.p. Illustrated — 1/150 h.p. 2,500 r.p.m. Suitable for light mechanical drives or fan duty.



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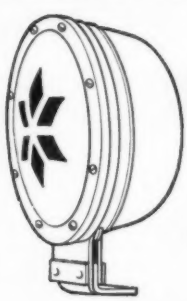

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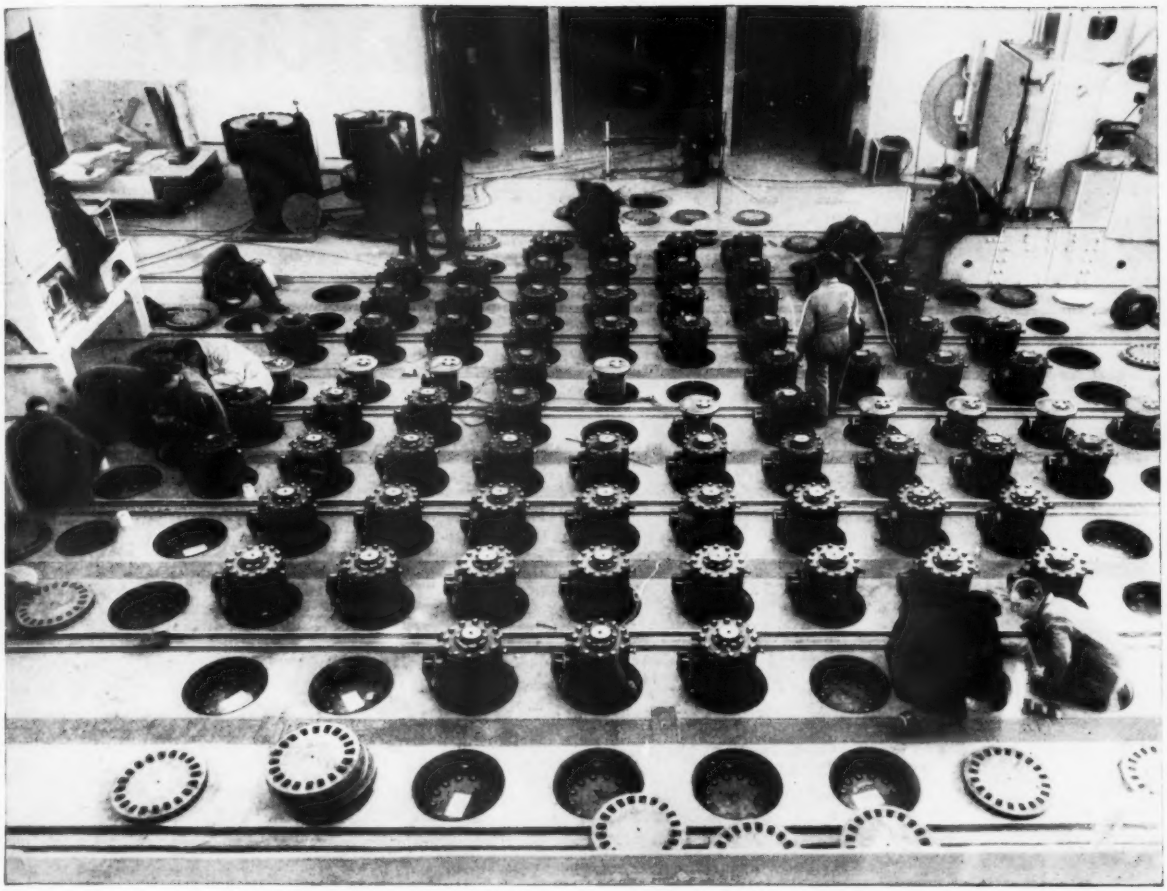

Controlling the reactors

AT CALDER 'A' Metropolitan-Vickers was responsible for the reactor control scheme and has supplied 120 actuating mechanisms and ancillary equipment. These mechanisms are for operating the combined control and shut-off rods and are arranged to provide a slow " out " and two faster " in " speeds. They will hold the rods in any required position and provide a controlled shut-off of the reactors independent of the electrical supply.

The pile cap during the installation of the control rod mechanisms at Calder Hall, Britain's first atomic power station. M-V is also responsible for the reactor control schemes at the Calder 'B' and Chapelcross power stations of the U.K.A.E.A., a further 360 actuating mechanisms being involved.

METROPOLITAN-VICKERS
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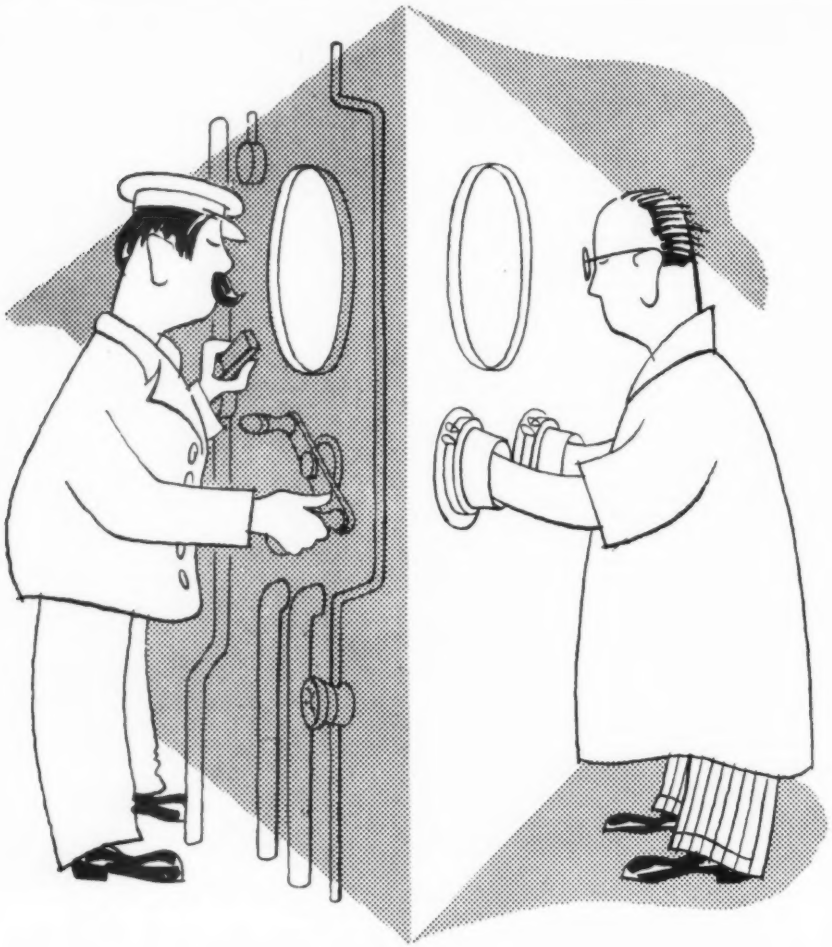

The other side of the picture

Since the earliest days of steam, asbestos has helped to conserve heat. At the turn of the century, for example, the boilers of locomotives were snugly wrapped in an asbestos mattress. Steam lines in the power station of the future will use asbestos pre-formed blocks and pipe sections, not only to conserve the heat and energy coming from the heat exchanger to the generating plant, but also, perhaps, on the coolant lines as well.

100% Amosite Asbestos, in the form of CAPOSITE, will provide insulation that combines high thermal efficiency with durability. Amosite is found in South Africa, and comes from mines belonging to the Cape Asbestos Company.

At the Atomic Energy Research Establishment in Harwell, another product of the Cape Asbestos Company—CAPE BLUE ASBESTOS—is already in use. Mixed with cotton, it is made into filters to purify the air against the effects of radioactive particles.

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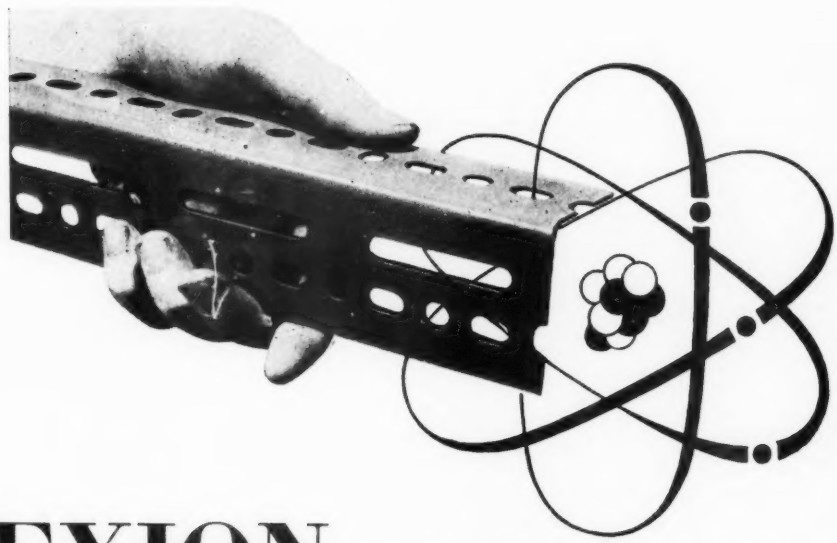

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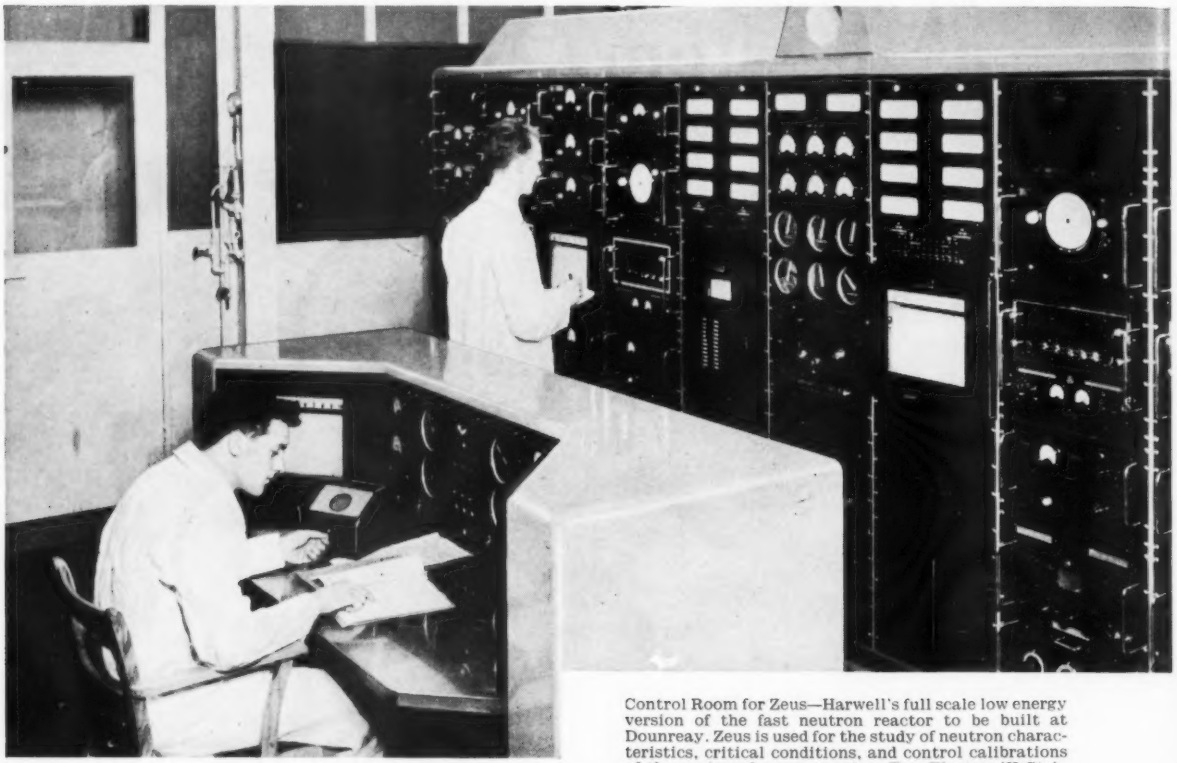
Honeywell Instrumentation at Harwell



Control Room for Zeus—Harwell's full scale low energy version of the fast neutron reactor to be built at Dounreay. Zeus is used for the study of neutron characteristics, critical conditions, and control calibrations of the projected power reactor. Two ElectroniK Strip Chart Recorders and an ElectroniK Multiple Point Precision Indicator are shown on the panel. Another Honeywell Recorder forms part of the control desk.

DIMPLE, ZEPHYR, ZEUS, DIDO, and now LIDO —on all these research reactors, ElectroniK instruments indicate and record critical variables. These include log count rate, log power, linear power, reactor period, and reactor temperatures. By permitting reactions to be safely controlled and minutely examined, Honeywell instruments contribute to the success of future atomic power stations.

VERSATILE INSTRUMENTATION A tour of Harwell is a tour of ElectroniK applications. Apart from reactor research, Honeywell instruments are used in many of Harwell's ancillary research departments—including those concerned with chemical engineering, health monitoring, physics, electronics, chemistry, and metallurgy.

TROUBLE-FREE PRECISION 'For laboratories and steelworks'—this sums up the qualities of ElectroniK instruments. Research workers value the unique accuracy, sensitivity, and operating speeds of these instruments. Their rugged construction, mounting freedom, and trouble-free service are equally attractive to scientists and industrial engineers.

Specific information is immediately available from Honeywell-Brown Ltd., 1 Wadsworth Road, Perivale, Middlesex. *Branch offices in the principal cities of Britain and Europe and throughout the world.*

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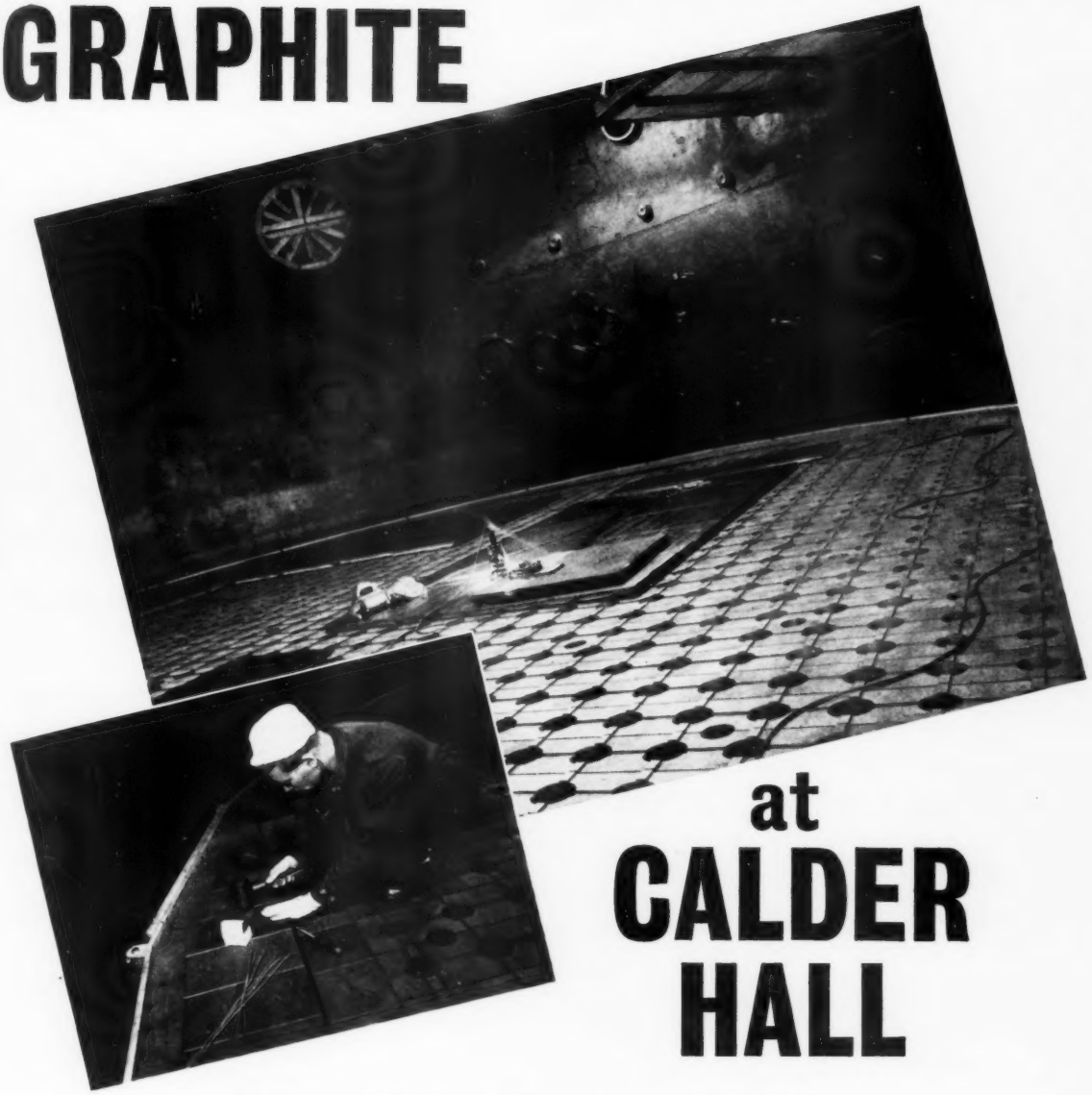

at CALDER HALL

Graphite, specially shaped, dimensioned and formulated for specific atomic energy applications is thoroughly job-proven. The first reactors built used graphite. Today these reactors continue to produce material for our atomic energy programme and they continue to depend on high purity graphite for their operation. Other reactor moderators—water, heavy water, various metals and oxides—have undergone experimentation, pilot plant study and actual construction. But, the use of graphite in the reactor is proven from the standpoint of economy, dependability and safety.

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Our wide experience is at your disposal, and we will gladly send technical representatives to advise on any problem involving insulation control of heat, cold or sound.

In spite of rising production costs we have decided to maintain present prices of Magnesia products to the end of 1956.

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in collaboration with

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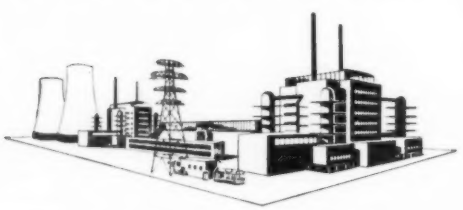
were responsible for the

design and production of

Specialised Detection Gear

installed at

CALDER HALL



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Shaping the Future

Skill doesn't come easily. It has taken more than 12 years of close association with the development of Atomic Energy for Marstons to build up the specialized technical knowledge they possess in this field. Marston Excelsior, from the start, have been among the foremost suppliers of specialized equipment to the U.K.A.E.A.— equipment for the first large-scale diffusion plant in this country; plate type fuel elements for the research reactors Dido, Lido and Dimple; stainless steel gas coolers for Calder Hall. It is this past experience that is helping Marstons to shape the future with such precision.

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AT CALDER HALL

this complex bundle of precision made tubes is part of the monitoring system. In any problem of specialized fabrication, Marstons will most likely have the answer.

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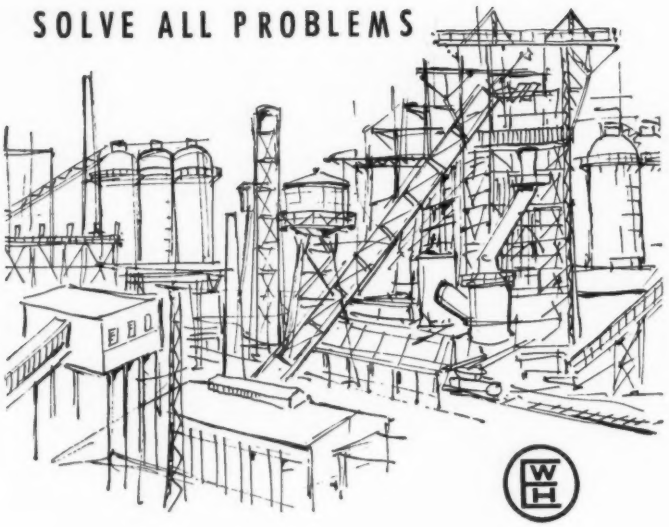

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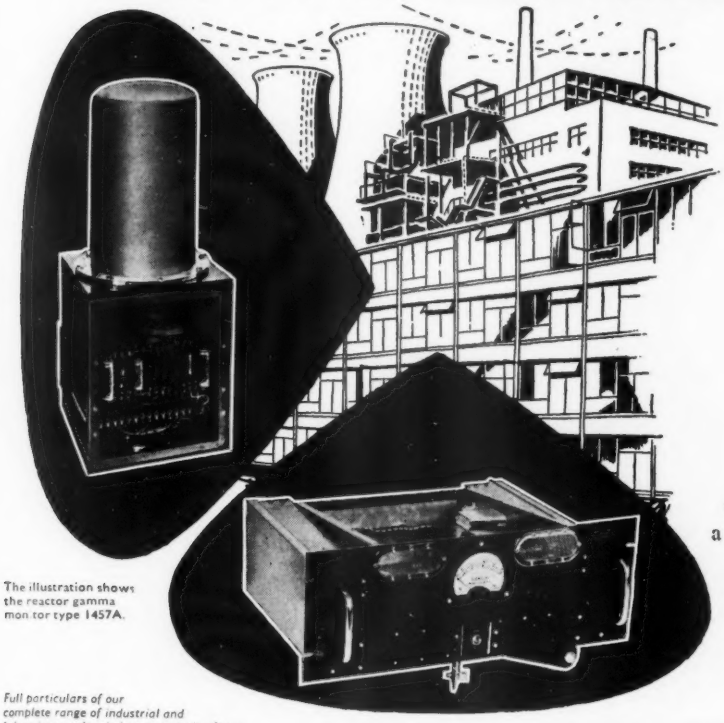
Calder Hall uses I.D.L. Nucleonic Instrumentation



The illustration shows the reactor gamma monitor type 1457A.

Isotope Developments Limited, as specialists in the industrial and research application of atomic energy, are playing a part in the instrumentation of the Calder Hall Power Reactor.

Besides specific instruments for Calder Hall, Isotope Developments are engaged upon an extensive programme of commercial reactor instrumentation. Amongst their present projects are the Nucleonic instrumentation of the "Merlin" (Medium Energy Research Light Water Moderated Industrial Nuclear Reactor) experimental reactor produced by the A.E.I. John Thompson Nuclear Energy Co. Ltd., and acting as consultants and suppliers of instruments for a number of European and overseas reactors.

ISOTOPE DEVELOPMENTS LTD.

Full particulars of our complete range of industrial and laboratory nucleonic instrumentation from:

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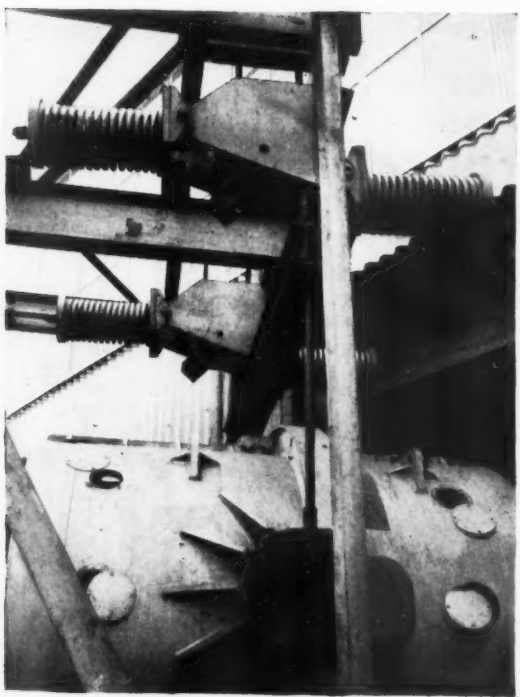
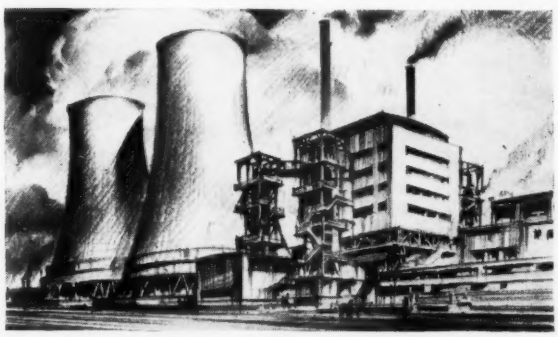
London Office: 120 Moorgate, London, E.C.2. *Tel: METropolitan 9641*





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specified for Calder Hall

Vokes Genspring pipe support systems are acknowledged to be the finest and most accurate available. As the first unit in a revolutionary departure from normal power generation, Calder Hall must have only the best in equipment—and for this important pioneer in nuclear power generation, we supplied C. A. Parsons & Co. Ltd., one of the main contractors for this station, with the latest in the range of Vokes Genspring Constant Support Hangers to support the mass of complex piping.
Vokes W.3 and W.4 hangers and their associated fittings are used extensively in both the 'A' and 'B' stations. The hangers shown can wthstand a load of 30,000 lb. over a travel of $3\frac{3}{8}$ ins. or 8,400 llb. over 12 ins.

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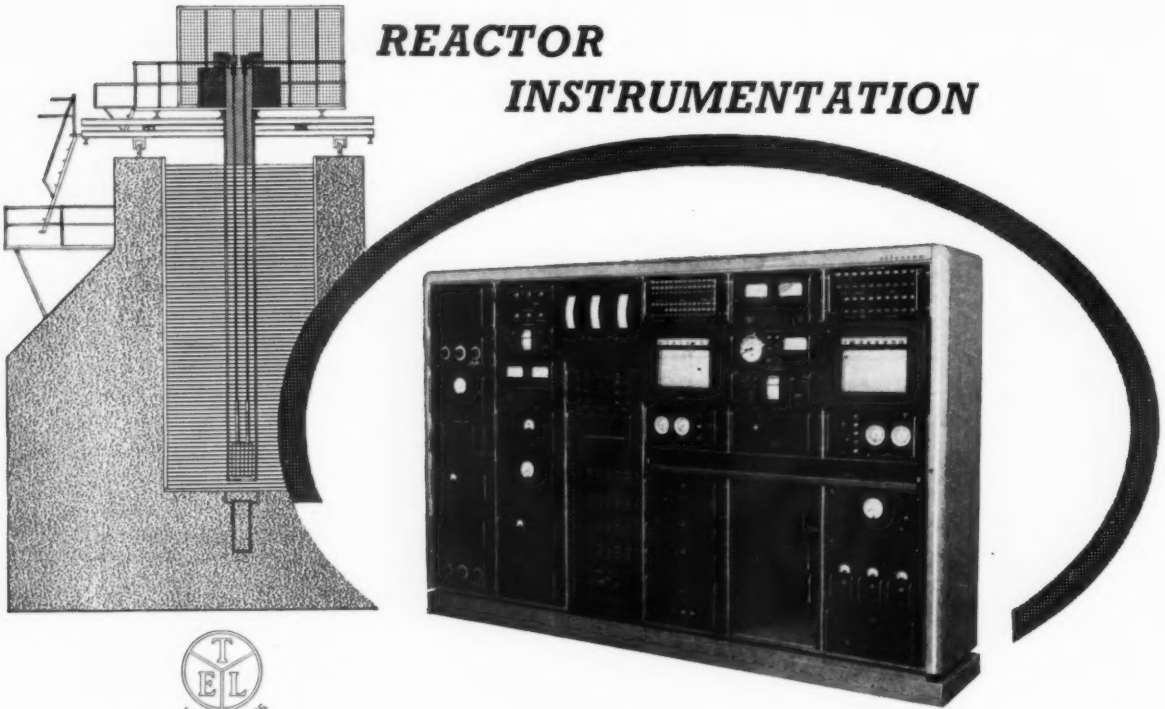
REACTOR INSTRUMENTATION



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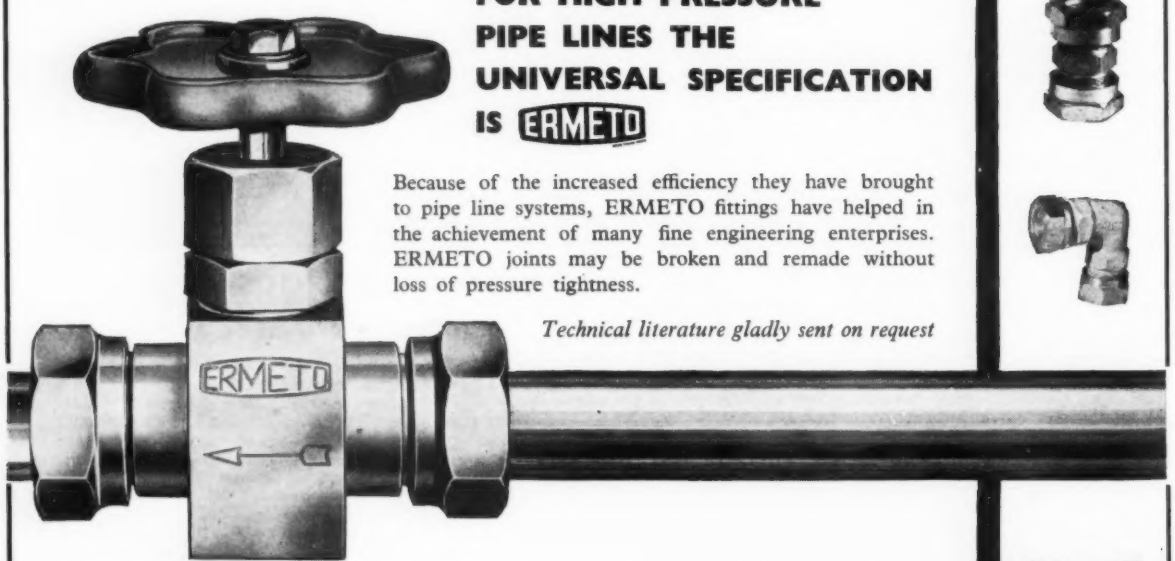
The Main Control Panel for "LIDO" Swimming Pool Reactor, including the Measurement, Control and Safety circuits, designed and installed by Ericsson Instrument Division in collaboration with A.E.R.E. (Harwell)

E52A



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The transition times of the output pulses are compatible with most present-day oscilloscopes. The internal sweep circuit makes it possible to deflect an inexpensive oscilloscope by direct connection to the deflecting plates, to monitor the output pulse.

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Radio navigation	Telemetering
Television	Physiological research

DESCRIPTION The Pulse, Sweep and Time-Delay Generator consists of the following major circuit groups: (1) input synchronizing circuits, (2) delay and coincidence circuits, (3) sweep circuits, and (4) pulse-timing and pulse-forming circuits.

3 INSTRUMENTS IN 1

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This is truly a *complete* Time-Domain Measuring Instrument, giving the best performance obtainable with ultra-modern techniques plus the finest obtainable materials and components, backed by over forty years manufacturing experience. A very well thought-out design, developed over several years, provides the pulse specialist with the equipment he has long been seeking.

SUPERIOR PULSE CHARACTERISTICS:
Excellent Rise and Decay Times: 0·025 ± 0·01 μsec. No Duty-Ratio or Frequency Restrictions on the Pulse.

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TIME DELAY: 1 μsec—1·1 sec.
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OUTPUT IMPEDANCE: 0-600 ohms.

This is a large instrument, and it is supplied complete with its necessary power supply (not illustrated), arranged at choice for bench or rack operation. The Generator proper has thirty-six vacuum tubes. Considering its flexibility and completeness the price is reasonable —£1,047 net delivered (U.K. only). For complete data see the 13-Page article in "GENERAL RADIO EXPERIMENTER" for May 1956, (Vol. 30, No. 12) or request the latest "G.R." Catalogue 'O' Send your written application to our nearest address, please.

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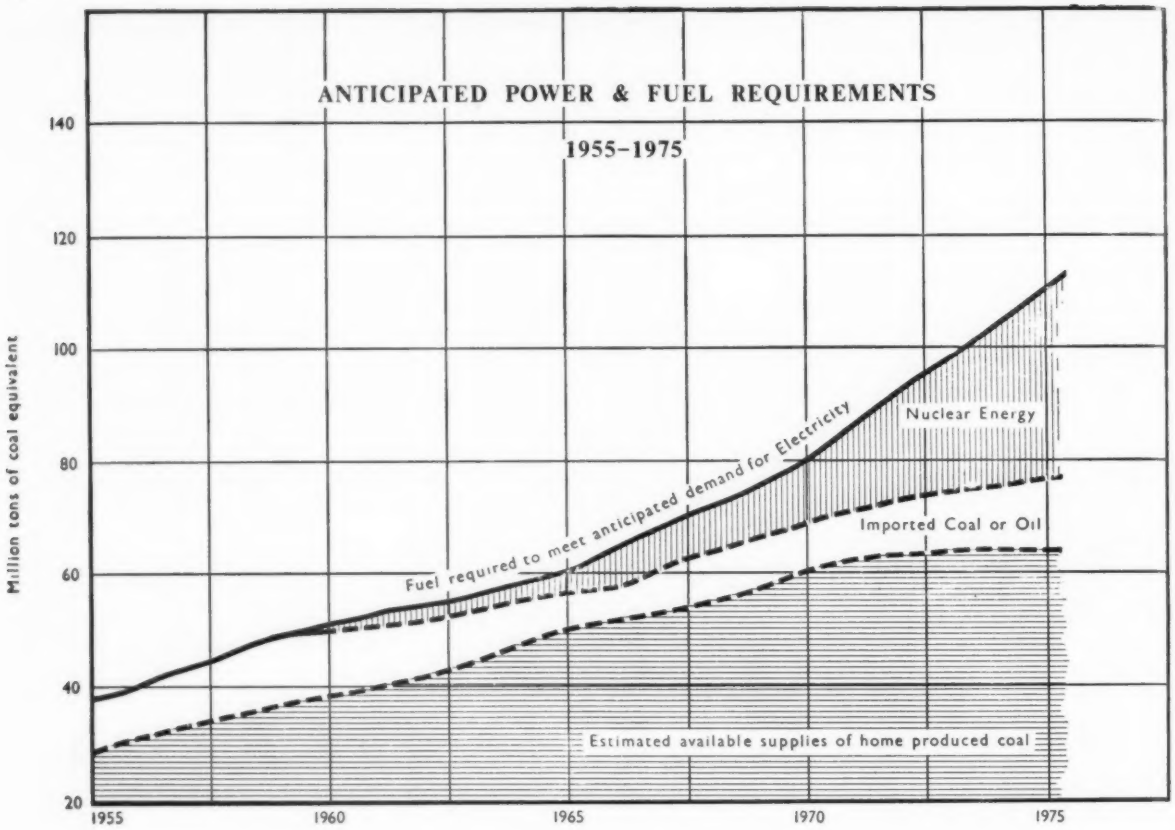


Electricity from Nuclear Energy

A 20-year development programme

Britain's nuclear power station construction programme will go far to offset the growing shortage of coal in the next two or three decades.

The First Ten Years

Work will start on the first two nuclear power stations in 1957. These will each have two gas-cooled reactors and the stations will be in operation by 1960/61. Two further gas-cooled reactor stations — each housing two reactors of improved type — to be begun in 1958/9 will come into service by 1963. The output of these four stations will be between 400,000 - 800,000 kilowatts.

The construction of two groups of four stations each will begin in 1960 and 1961/2 and they will be supplying electricity to the Grid by 1963/4 and 1965 respectively. The first group of stations will probably have one gas-cooled reactor each. The second will probably utilise liquid-cooled reactors — one high rated reactor each. These stations will add well over 1,000,000 kilowatts to the nation's power resources.

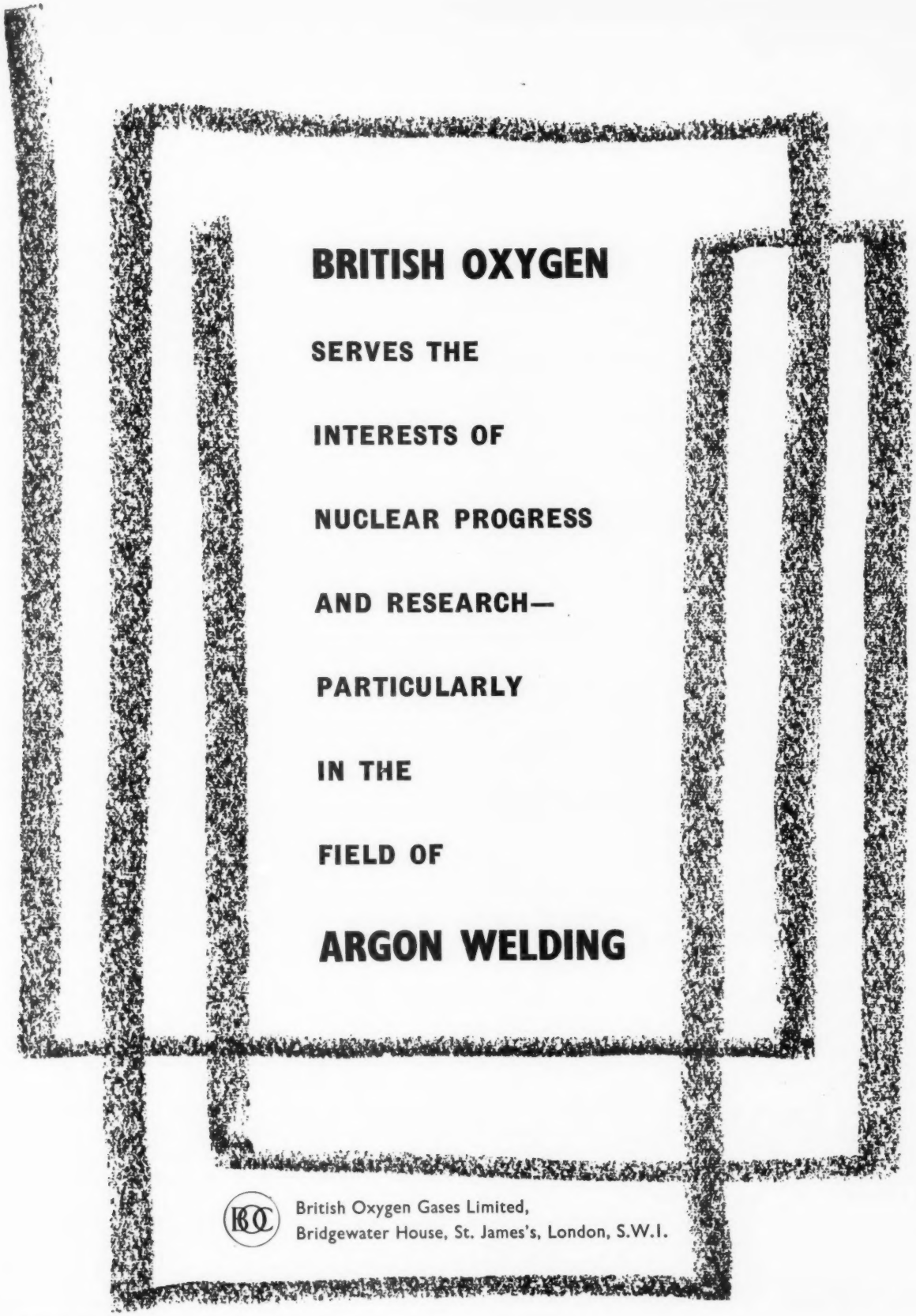
The Second Ten Years

By 1975, it is anticipated that nuclear reactor power stations in Britain will have an aggregate installed capacity of between 10,000,000 and 15,000,000 kilowatts. Since these stations will be operated as base load stations working at full output for twenty-four hours a day they will be responsible for possibly half the units generated in the country.

CEA

ELECTRICITY FOR PROSPERITY

In ten years' time — 1,500,000 to 2,000,000 kilowatts of nuclear power. In twenty years' time — 10,000,000 to 15,000,000 kilowatts of nuclear power, equivalent to 40-50,000,000 tons of coal a year.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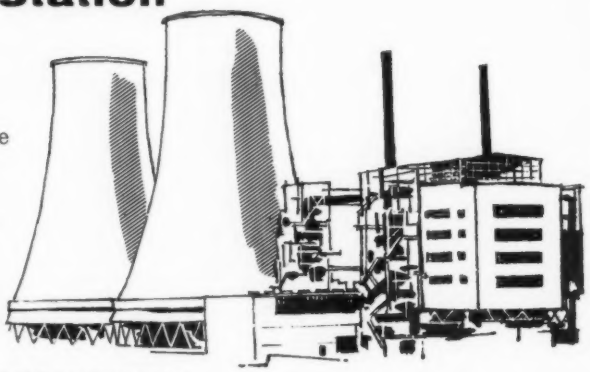

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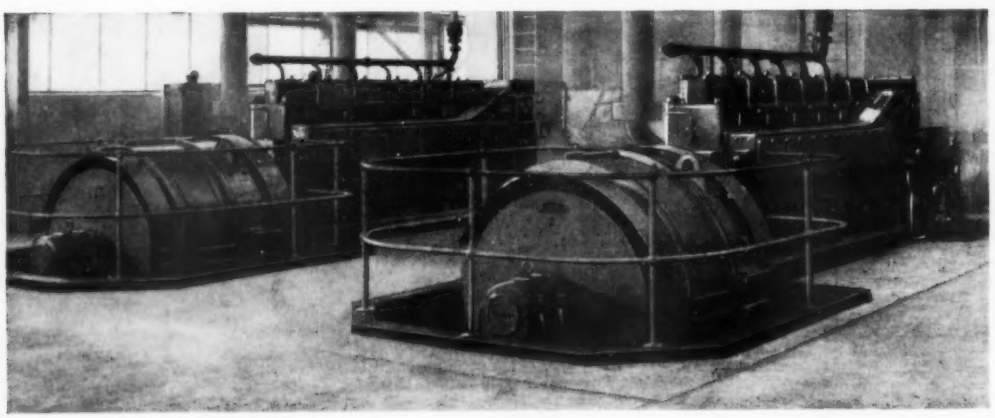

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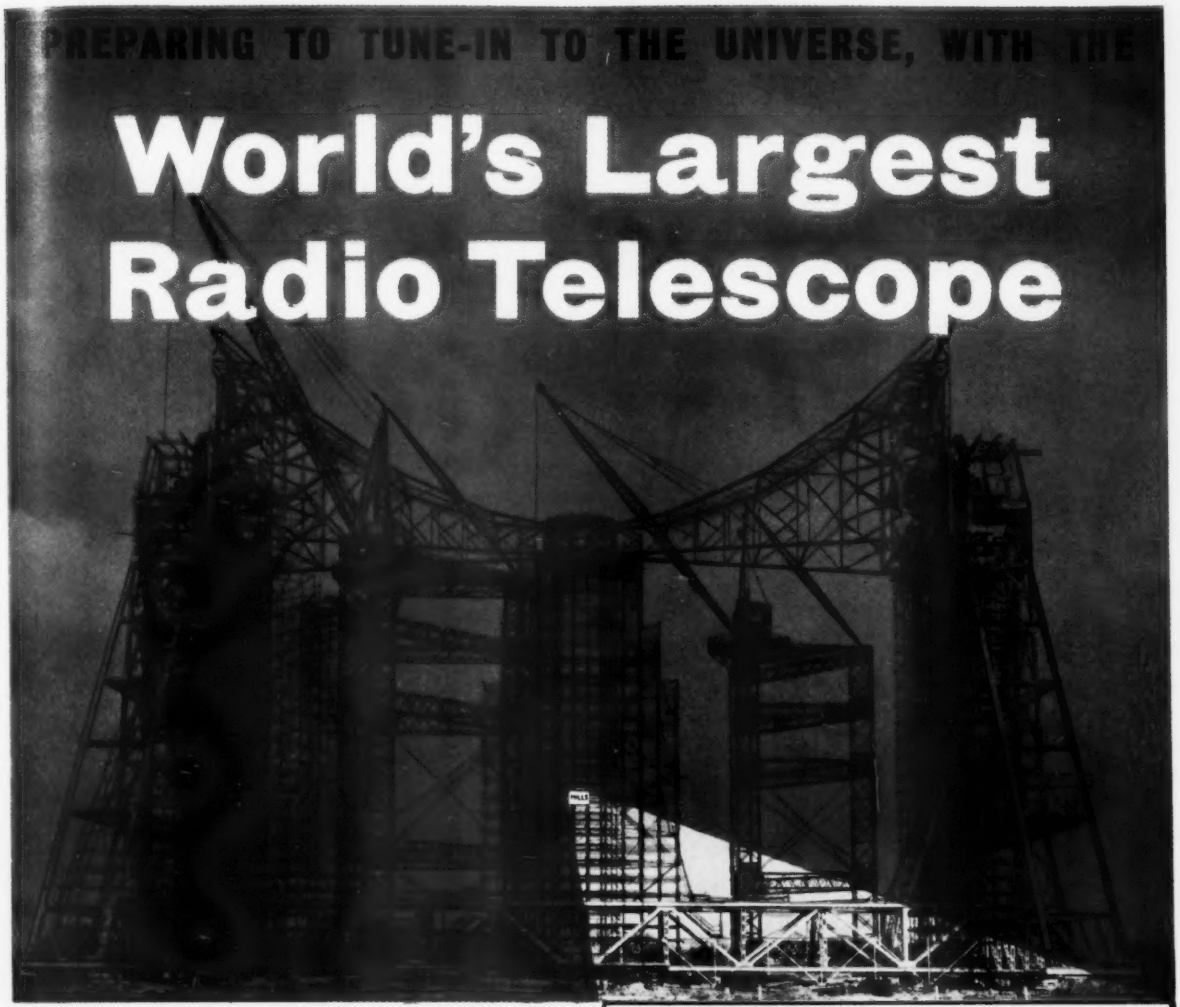

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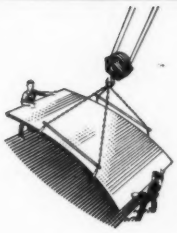

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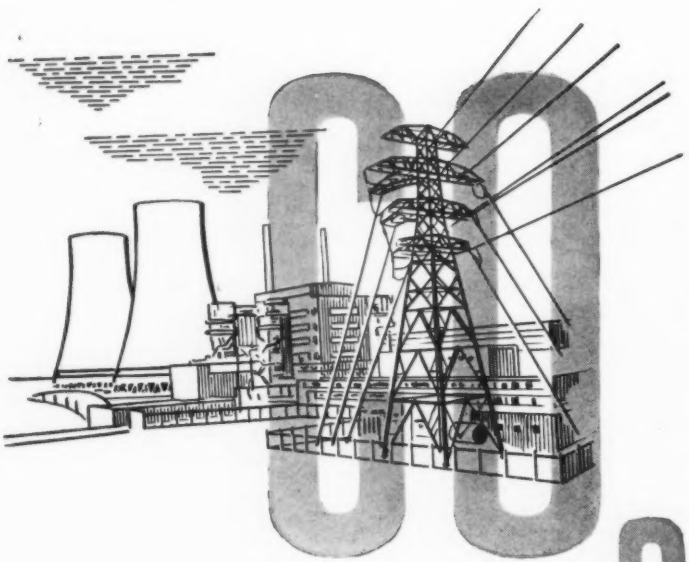
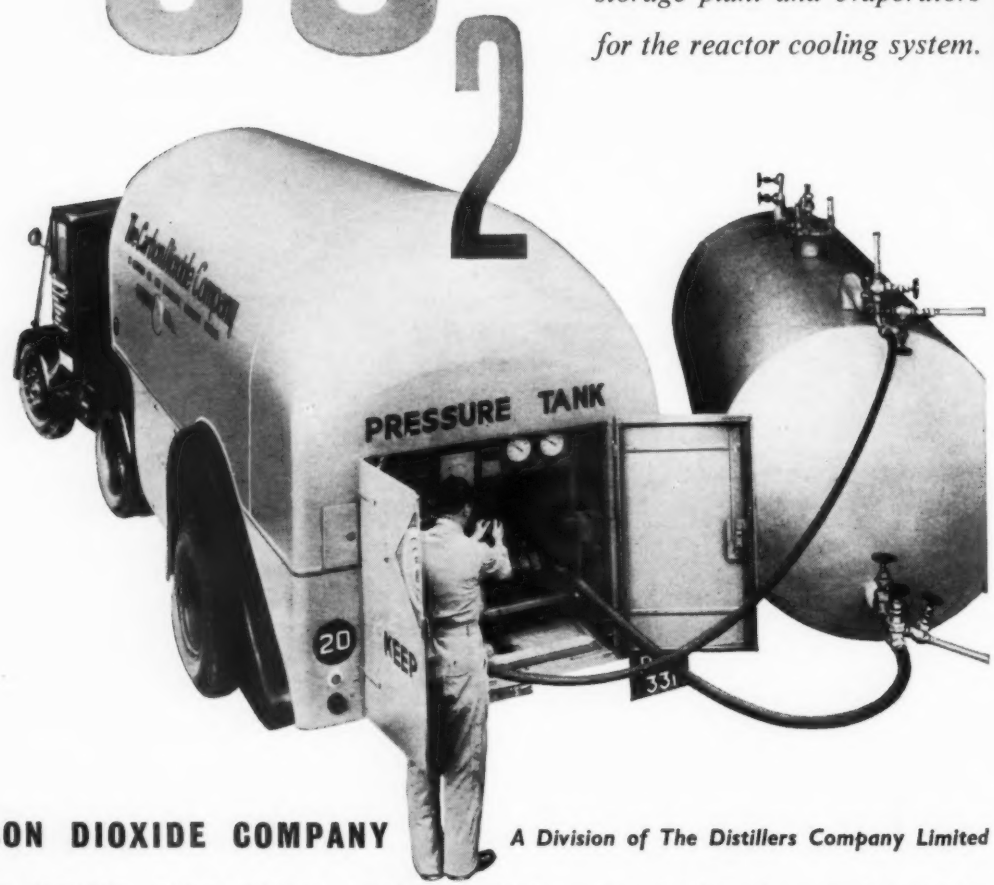


is manufactured, conveyed and delivered in road tank vehicles to Calder Hall by ***The Carbon Dioxide Company*** *(a Division of The Distillers Company Limited) who also designed, supplied and installed the CO_2 storage plant and evaporators for the reactor cooling system.*



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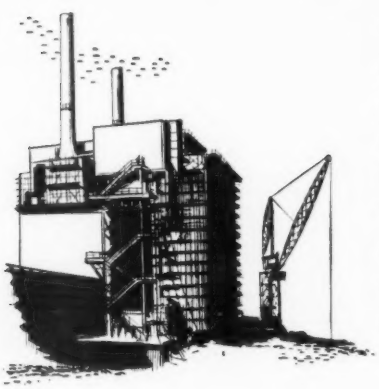

The 54 in. diameter cast steel motor-operated sluice valve illustrated here is one of a batch of 16 for the U.K. Atomic Energy Authority's first nuclear power station at Calder Hall. Repeat orders received include 16 similar valves for Calder Hall 'B', and 32 for the second atomic power station at Chapel Cross. The valves are for handling reactor cooling gas, at temperatures up to 700°F. Our long experience in the production of valves for conventional power plants and other applications provides the best possible background for handling the exacting requirements of this new development, and we offer our full collaboration in meeting any special valve problems that may arise.

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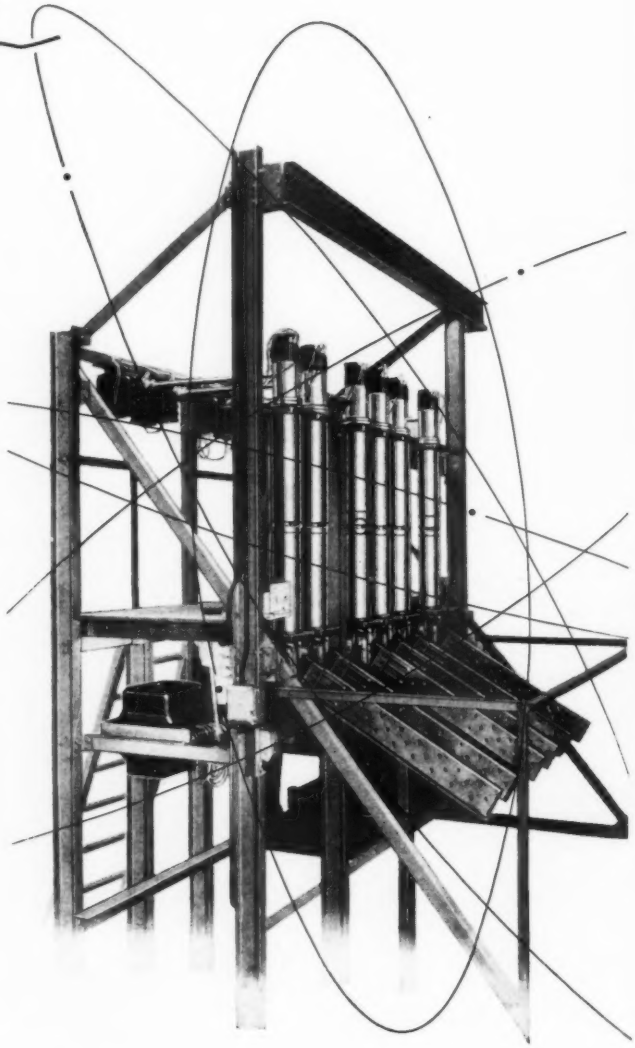
A step in a nuclear direction



H. M. HOBSON LTD. have for many years specialised in the design and manufacture of aircraft components calling for the highest degree of ingenuity and precision engineering. Although these activities continue in full swing, the Company have now entered the nuclear field and are engaged in the design and production of reactor control components and other ancillary equipment in collaboration with the Atomic Energy Authority. These items include the control systems for the following important Research Reactors: E.443 (Dido) for Harwell, A.E.443 for Sydney, Australia, and the R.E.775 (Pluto) for Harwell and Dounreay. Design, development and manufacture is proceeding on an automatic machine for introducing isotope specimens into the reactor and removing them after the requisite irradiation time; precision small pressure vessels and other experimental equipment for testing samples of various materials in the reactors; and control mechanisms for a new zero energy reactor.

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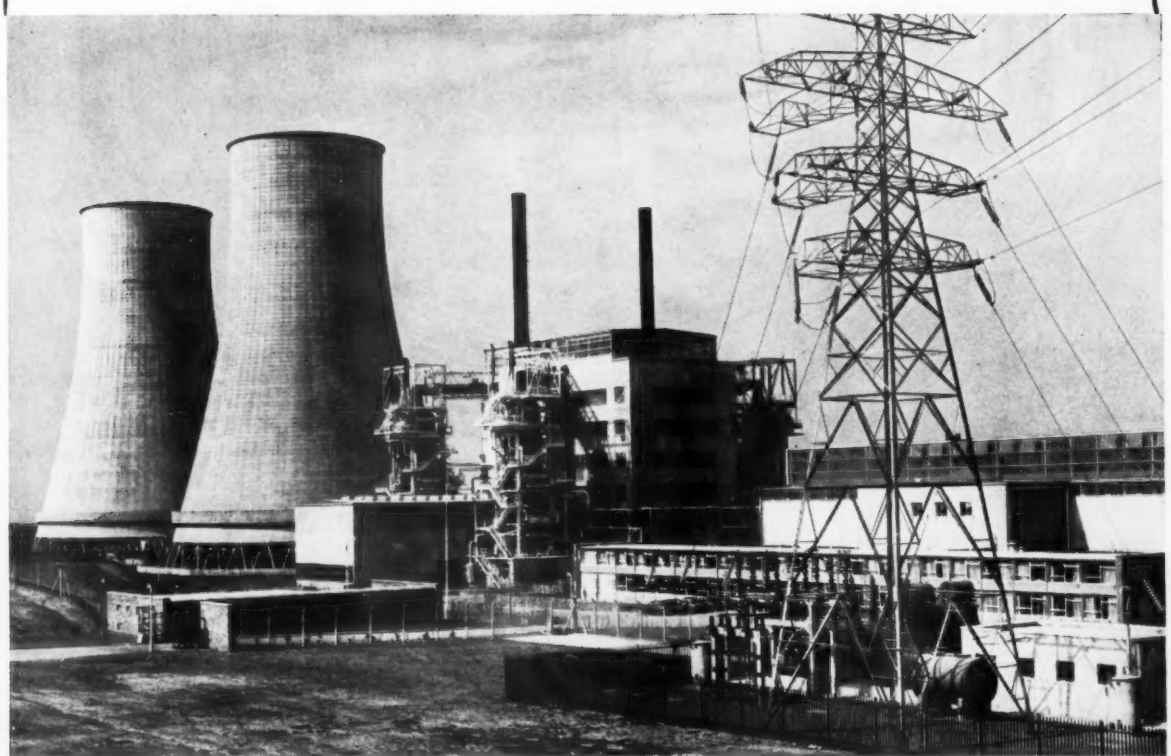
I.C.I. Tubes & Plates at Calder Hall



The biggest contribution of non-ferrous metals to the condensing plant at Calder Hall will be made by I.C.I.

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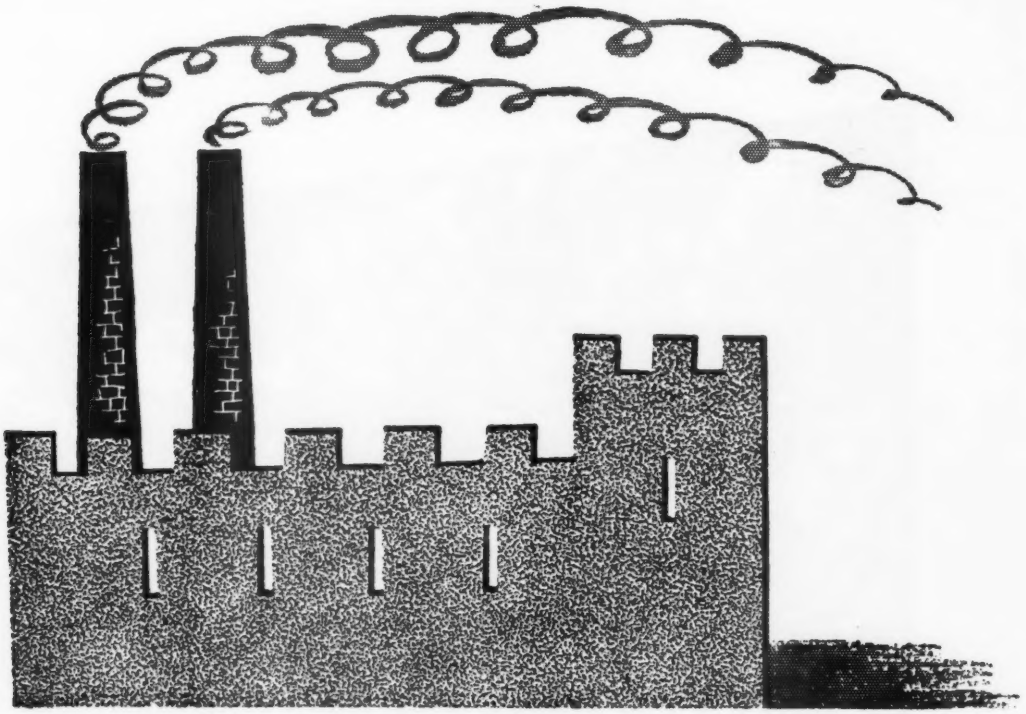

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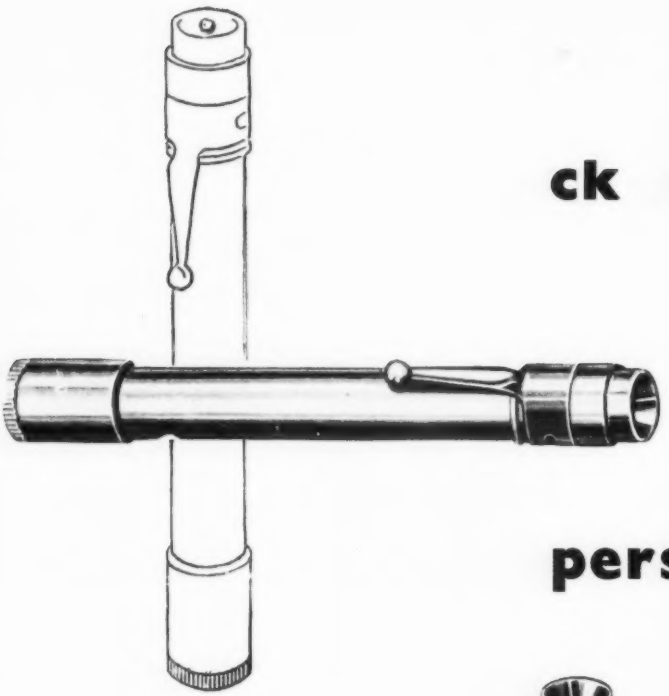

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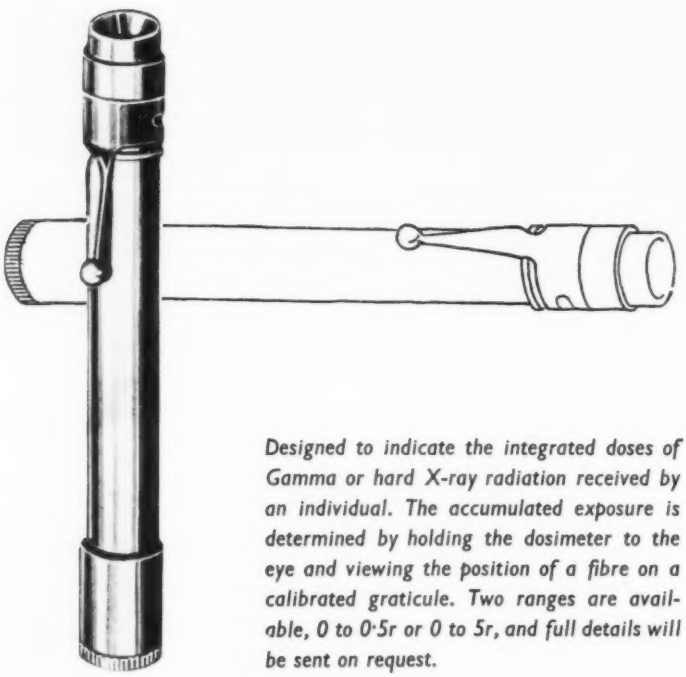
personal monitor



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Calder Hall. The No. 1 reactor control room, showing the control desk and KENT instrumentation (courtesy UK Atomic Energy Authority)

With the opening by H.M. the Queen of the first large-scale nuclear power station on earth at Calder Hall, Britain proudly demonstrates an ascendancy in a new world industry.

KENT takes equal pride in having been intimately associated with every major post-war nuclear development. From the earliest Harwell experiments to the latest power stations at Calder Hall and Chapelcross, the design, supply and installation of measuring instruments and control panels have been largely entrusted to KENT.

Instruments supplied include thousands of KENT Multelec recorders for the measurement and control of radioactivity, reactor power level, pH, conductivity, B.t.u. and temperature; KENT flow recorders and draught gauges for the measurement of air, steam and gas; and hundreds of complete control panels.

The valuable experience thus gained, added to substantial participation by KENT in closely allied industries such as steam generation, places the Company in the strongest possible position to contract for the engineering and building of instrumentation for all nuclear-power projects.

Whatever the future may hold for this new industry, KENT is destined—and qualified—to play a leading part in it. As and when entirely new types of instruments become necessary, KENT, with its unrivalled resources of knowledge and experience, is equipped to produce them.

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MASTERS OF INSTRUMENTATION

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UKAEA Photo

Murex at Calder Hall Nuclear Power Station

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Murex electric arc welding equipments are also being extensively used in the construction of Britain's various atomic energy plants. These products backed by the resources of the Murex organisation are at your service.

Among the contractors who have used Murex electrodes extensively at Calder Hall nuclear power station are Whessoe Ltd., Taylor Woodrow Construction Ltd., Matthew Hall & Co., Ltd., and Alex. Findlay & Co., Ltd.

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october 1956
volume I
number VI

Nuclear Power

The journal of British nuclear engineering

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Nuclear power for the nation's future

AN EXAMPLE of industry pooling its resources to prepare for a mighty project is the linking of the A.E.I.—John Thompson Nuclear Energy Company with two important firms of Civil Engineering Contractors—Balfour Beatty and Co. Ltd., and John Laing and Son Ltd.

To the strength of the A.E.I.—John Thompson Nuclear Energy Company and its constituents (British Thomson-Houston, Metropolitan-Vickers and John Thompson) is added a fund of knowledge in the civil engineering field.

The Balfour Beatty Group has a world-wide reputation in all forms of engineering and construction work and is at present carrying out major contracts for the Central Electricity Authority.

John Laing and Son Ltd. has carried out building and civil engineering work at the first Government Atomic Energy Establishment at Windscale and is at present engaged in the construction of power stations in the United Kingdom, as well as in major development schemes in Canada.

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Nuclear Power
OCTOBER 1956 VOLUME I NUMBER VI

October Seventeen, 1956

IN A FEW DAYS TIME The Queen will travel to Cumberland to perform an action which will have far more than local, or even national, significance. When she operates the switch at Calder Hall on October 17th, for the first time in any country of the world electricity generated entirely from nuclear fission will be fed to a national power network—not as an experiment or as a propaganda stunt, but as the start of a regular service which is destined to grow rapidly. This simple deed will mark in the most fitting manner possible the culmination of years of painstaking and skilful effort and will have the most far-reaching repercussions not only in this country, but throughout the world.

For Britain, the event will inaugurate officially the start of a new era in our industrial history. Faced with the hard facts that our coal production is virtually at a maximum —indeed we are having to import coal—and that our oil supplies are at the mercy of politics, the commencement of the atomic age in this country means that we can now be certain that our industrial economy will advance, confident that there will be no lack of power. Admittedly, nuclear fuel also has to be imported, but it comes largely from Canada and other Commonwealth countries and is not a pawn in the game of international politics.

Criticism was expressed at Geneva as to the wisdom of Britain investing so much in the gas-cooled graphite-moderated pile. This was effectively answered at the time by Sir Christopher Hinton but if any doubters still remain, let them travel to Calder Hall and see for themselves the triumphant answer of a dedicated team of scientists, engineers and craftsmen. Calder Hall may be the 'reciprocating engine of the reactor world'—as Sir Christopher himself described it—but it should not be forgotten that after more than a century this form of motive power is still driving the majority of the world's transport. Whether the water-cooled graphite pile would have been more economical we shall probably never know—it may find application in other countries but for us, it is clear that the choice we made in 1952 was the correct one.

The achievement of Calder Hall lies in the fact that despite doubts and criticisms, the design was finalized, construction pushed ahead and completion brought about on schedule of what must rank for all time as one of the most remarkable of man's works on earth. It is true that for sheer size and variety the various Manhattan plants of the United States exceed it but they were built under the stress of war with no regard to expense: Calder, although of some military significance, had to be as economic as possible for it was to be the archetype of a whole ten-year programme of large-scale nuclear power. Although in a sense it is a prototype there is nothing makeshift or tentative about Calder: it is a striking power station in its own right. Astonishingly simple now it is built, four years ago when it was still at slide-rule stage, problems which are now hardly apparent as problems seemed formidable indeed and all honour is due to the confidence and skill of the men who built it.

Those who are present at Calder Hall on October 17th will be privileged. Like the multitude who gathered at Liverpool on September 15th 1830 to see the first regular steam train leave for Manchester, or like the few who were at Dover on July 25th 1909 to see Blèriot land, they will be sharing in the making of history. Incidentally, if it is of any significance, Risley, the headquarters of the AEA Industrial Group, where Calder was largely designed is almost within sight of that same Liverpool and Manchester railway whose construction 126 years ago marked the start of a new age in communications. There will be many more nuclear power stations in this and other countries and they will no doubt be better than Calder Hall. But in the history books, it is Calder Hall A that will take its rightful place as the first completely new source of power to be harnessed on any scale for centuries.

Reactor Instrumentation

Ekco Electronics have made vital contributions to the instrumentation of the existing reactors at Harwell and Calder Hall, and are responsible for the nucleonic instrumentation of the reactors under construction in Australia, and at Harwell and Dounreay. This marks yet another important step in the long line of Ekco achievements in nucleonic measurement—a field in which we were pioneers and in which we continue to lead.

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THE ATOMIC ENERGY AUTHORITY'S GREATEST DAY

Calder Hall to be opened by Her Majesty

ELECTRICITY FOR NATIONAL GRID

THE FIRST FULL-SCALE nuclear power station in the world is now producing electricity. This outstanding achievement of British scientists, engineers and craftsmen is to receive Royal recognition on October 17 when Her Majesty Queen Elizabeth II will visit Cumberland to inaugurate officially Calder Hall A power station of the United Kingdom Atomic Energy Authority.

For some time No. 1 reactor has been raising steam and the turbines have been run, but so far the power produced has been used internally in the Calder Works and at the nearby Windscale plutonium factory. When the Queen visits the power station, she will operate a switch and for the first time, electricity will go out to the 132kV National Grid of the Central Electricity Authority. The station is expected to have cost about £16M, of which £7M was for the reactors. A full description of the power station commences in this issue of NUCLEAR POWER: it will be continued in the November and December issues. The November issue will also contain a full and illustrated account of the Queen's visit.

The ceremony will take place on a dais on a lawn outside the administration block. Stands have been erected for members of the AEA and their guests and there is also an enclosure to which the public will be admitted free.

The Royal train will arrive at Sellafield station at 10.00 am and Her Majesty will be welcomed by the Lord Lieutenant of Cumberland, Sir Robert Chance. The Queen will then drive to Calder Hall where she will be received by Sir Edwin Plowden, Chairman of the UKAEA, who will make presentations to Her Majesty. Preceded by explanations of the plant and a visit to a special exhibition, the Royal party will then be shown over the plant. At 12.00 midday, accompanied by the Lord President of the Council, Lord Salisbury; the Lord Lieutenant of Cumberland; the Minister of Fuel and Power, Mr Aubrey Jones; Sir Edwin Plowden; Sir Christopher Hinton, Managing Director of the Industrial Group; and Mr W. L. Owen, Director of Engineering, The Queen will ascend the dais for the ceremony. The royal speech will culminate with Her Majesty pressing the button at 12.15 and a giant meter erected on the administrative building will indicate that electricity is being passed out to the grid.

After luncheon at the station, Her Majesty will leave at 2.00 pm and then guests of the UKAEA will be shown over the plant.

Among the distinguished visitors expected at the ceremony are: Mr W. B. Lewis, Vice-President, Atomic Energy of Canada Ltd, Dr H. J. Bhabha of India, Prof. Niels Bohr of Denmark, Pierre Guillaumat and Francis Perrin of the French CEA, Federal Minister F. J. Strauss of Germany, Matsutaro Shoriki of Japan, Harold S. Vance, United States Atomic Energy Commissioner, and Academician A. V. Topchiev of the USSR Academy of Sciences.

How to get there

Road: From the South: Leave A6 at Levens, 10 miles north of Carnforth and take A590 to Dalton in Furness. Follow A595 to Calder Bridge. From the North: A595 to Calder Bridge from Carlisle. From the North East: A594 from Penrith to join A595 at Cockermouth.
Train: by British Railways to Seascale.

WORLDVIEW

British turbine for NPD

Atomic Energy of Canada's NPD power reactor which is to be built at Des Joachims (pron. 'Desweeshims') on the Ottawa River is to have a British turboalternator set. Speaking in London on Sep 27, Mr Harry West, managing director of the AEI John Thompson Nuclear Energy Company revealed that the order for a 20MW set with condensing and feed heating plant had just been received by Metropolitan-Vickers, an AEI-JT constituent company.

NPD is a heavy water moderated and cooled reactor, fuelled initially with natural uranium. The primary conditions will be 500°F, 950 lb/sq in, exchanging to light water from which saturated steam at 400 lb/sq in. will be raised. The object of NPD is to demonstrate the potentialities of the type and provide data for reactors in the 100-200MW range. It is due for completion in July 1959. The reactor is being built by Canadian General Electric. The Metrovick order, which is worth $620,000 was obtained against competition from Britain and abroad.

Bradwell, Berkeley tenders in

Just before the Calder Hall opening, the British nuclear energy programme took another step forward. On Oct 1, the Central Electricity Authority received tenders for its first two power stations—those at Bradwell, Essex, and Berkeley, Gloucestershire. A ceremonial opening of the tenders was performed at the CEA's London headquarters by chairman Lord Citrine, the event being recorded on film for a documentary the Authority are to make.

The four groupings which submitted tenders are:—The AEI-John Thompson Nuclear Energy Co Ltd; the English Electric-Babcock & Wilcox group; The General Electric—Simon Carves Atomic Energy Group; and The Nuclear Power Plant Co Ltd. The specification calls for a graphite-moderated, gas-cooled reactor but it is understood that no power limits were set, it being left to the firms to provide as much as possible. This is believed to be in the region

of 250-300MW electric per reactor for most of the designs.

It will take the CEA—who will receive advice from the AEA—some three months to assess the tenders and the winning designs are expected to be announced early in January. The same groupings are also tendering for the South of Scotland Electricity Board's first station which is to be at Hunterston, West Kilbride, Ayrshire.

First British pool reactor starts

LIDO, the latest research reactor at Harwell, became critical for the first time during the night of 20/21 September. This reactor is intended primarily for shielding studies: one of its major tasks is to assist in the development of the British submarine propulsion unit.

It is a 'swimming pool' type reactor in which the enriched uranium plate-type fuel elements are suspended in a large concrete tank of purified water. The concrete tank is 24 ft deep by 8 ft by 28 ft and is surmounted by a movable trolley. Suspended from the trolley is a framework supporting the reactor core which is about the size of a tea-chest. Shielding experiments are made by moving the core of the reactor close to aluminium windows which are set into the walls of the tank. The heat output is about 100kW.

The detailed design and construction of the reactor was carried out by a joint Naval and Atomic Energy Research Establishment team in association with the following industrial firms: Vickers-Armstrongs (Barrow) Ltd (Reactor components); Ericssons Telephones Ltd (Instrumentation); Rolls Royce Ltd (Control Gear); Marston Excelsior (Fuel Elements); The buildings, including the reactor tank, were constructed by the Ministry of Works.

Reactor School's new look

When the Harwell Reactor School started its new course on September 10, students found a completely new building waiting for them. A single-storey block, planned on contemporary lines with full facilities for lectures, laboratory work and private study, the new school will allow many more students to be accommodated. The current course was heavily oversubscribed and is being taken by 20 men from 13 overseas countries, 20 from British industry and 15 AEA staff. The three-month course will include about 150 lectures, visits to British reactors in use or in construction and experiments on the Harwell BEPO reactor.

For the first time students are allowed—as a short introductory course—to take the first six weeks of the standard course. This is expected to appeal to lecturers from universities and technical colleges and to firms working in ancillary aspects of nuclear power: the full course is designed for industrial graduate engineers who will be engaged on reactor design.

The school's programme to the end of 1957 is as follows:

Feb 4 1957	course no 9— 6 weeks
	course no 10—14 weeks
June 3 1957	course no 11— 6 weeks
Sep 16 1957	course no 12— 6 weeks
	course no 13—14 weeks

Calder celebrated at Hong Kong

The Calder Hall opening on October 17 will be celebrated as far away as Hong Kong where, on that day, a three-day exhibition is to be opened in the British Council Reading Room. Covering 600 sq ft and including models, photographs, drawing and instruments, the exhibition has been organised by the UK Trade Commissioner to show how Britain is leading the world in the practical application of nuclear power. A feature of the exhibition will be regular showings of the Calder Hall film made by the Ace Film Unit. In addition to material supplied by the UKAEA, British firms, including General Electric, Babcock and Wilcox, Marconi's, Metropolitan-Vickers, John Thompson and the Scientific Instrument Manufacturers Association are cooperating in supplying material. It is planned to take the exhibition later to Manila in the Philippines.

Tripartite patent agreement

Britain, Canada and the United States signed last month an agreement to interchange patent rights in atomic energy. It was described as a 'cross-assignment', for each government assigns to the others all rights, titles and interests owned by it in those countries. Each assigning government retains a non-exclusive, irrevocable, paid-up licence on each invention for its own purposes and for mutual defence, but it means that now these inventions can be used in other signatory countries without interference. In these countries, licences to exploit will be granted by the government concerned.

November 15, 1955 was selected as the operative date and the agreement applies only to government owned patents in force at that date. These are of two classes: 1. CPC (Combined Policy Committee), which arose out of war-time collaboration. There are about 50 of these. 2. Inventions developed independently, but within the cooperative arrangement.

The agreement does not affect inventions employing information communicated under the UK/US bilateral agreement of June 15, 1955. Neither does it bind governments for the future.

Frederick Soddy dies

The death was announced at Brighton on September 22 of Frederick Soddy FRS, Emeritus Lee's Professor of Chemistry in the University of Oxford. Born at Eastbourne in 1877, Soddy was associated with Rutherford at McGill University when they demonstrated that radioactivity was caused by transmutation of elements. In 1904 he returned to Britain and became a lecturer at Glasgow. He then held chairs at Aberdeen and Oxford. He won a Nobel Prize in 1921 and retired in 1936 on the death of his wife.

Frederick Soddy will be chiefly remembered for his discovery in 1913 that the same chemical element can have different atomic weights. To these, he gave the name 'isotopes'.

ISRAEL

Uranium plant soon

In a joint Israel-United States exhibition at Rishon Le Zion, Israel, last month, opened by President Ben-Zvi, great interest was shown in Israeli work on the production of heavy water by distillation and

on the extraction of uranium from the Negev phosphates. This and other work is being done by the Weizmann Institute of Science, the Hebrew University of Jerusalem and the Israel Institute of Technology, working under the coordination of the Israel Atomic Energy Commission. A full-scale uranium plant is expected to be in operation soon.

The American part of the exhibition was opened by ambassador Lawson and was largely that shown at Geneva last year. In the meantime, the exhibition had been shown in Japan and several Arab countries.

UNITED STATES

GM choose British

British-designed air conditioning equipment was selected for the isotope laboratory of a new $175m Technical Centre, opened recently by the General Motors Corporation at Detroit, Mich. Situated on a 330-acre site, the Centre employs more than 4,000 workers, and consists of 25 buildings, housing both offices and laboratories, grouped around a 22-acre artificial lake.

The air conditioning plant uses a high-velocity system specially developed by the Scottish company of Thermotank Ltd. This was considered to be the most advanced in its field and was selected after consideration of the various American techniques available. The laboratory is being used for research with radioactive materials, in conjunction with the AEC, and the heating, ventilating and air conditioning system was designed to ensure a positive control of the air supply and exhaust, and thus prevent any possibility of contamination.

The main floor of the Laboratory is completely air conditioned, with the use of 100 per cent fresh air at all times, since any recirculated air would inevitably increase the possibility of contamination. A slightly reduced air pressure has been created in the laboratories in relation to the general office areas in the buildings to prevent flow from the laboratories into the offices. Special attention was paid to air filtration since the presence of dust particles in radioactive work could lead to dangerous conditions. All fittings are of stainless steel, and the exhaust ductwork is in mild steel pipe coated with acid-resistant rubberized chemical compound.

Europe HQ for International AEA ?

Vienna is being mentioned as the possible headquarters of the International Atomic Energy Agency, discussion of which started at the UN headquarters in New York on September 30. This conference—attended by 81 states—is the latest move arising from President Eisenhower's famous 'atoms for peace' declaration to the General Assembly in December 1953.

Last April a working committee of 12 states meeting in Washington produced a draft statute which is now under discussion. Talks are expected to last for about six weeks and it is hoped that Mr Eisenhower will be able to address it before the conference closes.

Huge AEC beryllium contract

The Brush Beryllium Co of Cleveland, Ohio, received last month an AEC order for 500,000 lb of reactor-quality beryllium to be delivered over a five-year period commencing January 1, 1958. According to Brush President, Bengt R. F. Kjellgren, the company will immediately start building a new plant between Elmore and Oak Harbor, Ohio, adjacent to the beryllium copper Alloy Division. The cost of this is expected to be about $4½m, the money to be raised by loans and a stock issue.

Brush Beryllium is at present the only industrial producer of reactor-grade metal and is currently operating the AEC facility at Luckey, Ohio, for this purpose.

Now the anti-neutron

Following the discoveries in recent months of the anti-proton and the neutrino, the anti-neutron has now also been positively identified. This was announced on September 14 by the University of California and the AEC. Working with the Berkeley Laboratory's Bevatron, the particle was found by Dr Bruce Cork, Dr Oreste Piccione, Dr Glen Lambertson and Dr William Wenzel under the leadership of Dr Edward J. Lofgren.

SA MAJESTÉ la Reine Elisabeth II va inaugurer le 17 octobre la centrale électrique nucléaire de Calder Hall à Sellafield, Cumberland. Ce sera la première usine du monde à alimenter un réseau national d'électricité produite exclusivement par la réaction de fission nucléaire. La chaleur nucléaire est produite dans deux réacteurs à l'uranium naturel, modérés au graphite et refroidis par de l'acide carbonique sous pression de 6,8 ata circulant dans le noyau du réacteur à l'intérieur d'un bac à pression en acier. Autour de chaque réacteur, mais à l'extérieur du blindage biologique, quatre échangeurs de chaleur sont disposés, dans lesquels la vapeur surchauffée est générée sous pressions de 13,6 ata (310°C) et 3,6 ata (171°C). La vapeur alimente quatre turbogénérateurs de 23 MW et 11,5 kV.
L'usine de Calder Hall est subordonnée à l'Administration de l'Energie Atomique au Royaume-Uni. Bien qu'un des objets de ce projet soit la production de plutonium, on a gagné déjà l'expérience importante qui va contribuer à augmenter d'une façon considérable le rendement d'énergie de nouvelles centrales électriques dont les projets sont élaborés pour l'Administration Générale d'Electricité.

IHRE KÖNIGLICHE MAJESTÄT, Königin Elisabeth II, wird am 17. Oktober die Kernenergiezentrale Calder Hall in Sellafield, Cumberland, eröffnen. Dies ist die erste Anlage in der Welt, aus welcher die ausschliesslich durch Kernspaltung erzeugte Elektrizität dem Landeskraftnetz zugeführt werden wird. Die nukleare Wärme wird in zwei Natururan-Graphitmoderator-Reaktoren erzeugt; die zur Kühlung verwendete Kohlensäure wird unter einem Druck von 6,8 ata in Reaktorkern innerhalb eines Druckbehälters aus Stahl zirkuliert. Um jeden Reaktor herum, aber ausserhalb des biologischen Schut schurms, sind vier Wärmeaustauscher angeordnet, in welchen überhitzter Dampf von 13,6 ata (310°C) und 3,6 ata (171°C) erzeugt wird. Der Dampf speist vier 23 MW-Turbogeneratoren, die eine Spannung von 11,5 kV erzeugen.
Die Anlage von Calder Hall ist der Britischen Atomenergiebehörde untergeordnet. Obwohl eines ihrer Ziele Plutoniumherstellung ist, ist es gelungen, wertvolle Erfahrung zu erlangen, die zu einer wichtigen Leistungsvergrösserung der jetzt für die Zentralbehörde für Elektrizität in Konstruktion begriffenen elektrischen Kraftwerken führen wird.

EL DIA 71 DE OCTUBRE, S.M. la Reina Isabel II inaugurará oficialmente la central electroatómica de Calder Hall en Sellafield, Cumberland. Esta es la primera instalación del mundo que suministrará a una red eléctrica nacional energía generada enteramente por la reacción de la fisión nuclear. El calor nuclear es obtenido de dos reactores de uranio natural, moderados con grafito y enfriados por bióxido de carbono que circula a través del núcleo del reactor, que va colocado dentro de un recipiente de acero a una presión de 6,8 ata. Alrededor de cada reactor, pero fuera de la coraza biológica, están agrupados cuatro intercambiadores térmicos, en los cuales se genera vapor recalentado a dos presiones — 13,6 ata, 310°C y 3,6 ata, 171°C. Este vapor es alimentado a dos turboalternadores de 23 MW que generan a 11,5 kV.
La central de Calder Hall depende del Consejo de Energía Atómica del Reino Unido, y si bien tiene en parte como objeto producir plutonio, con su erección se ha adquirido valiosa experiencia que contribuirá a la obtención de producciones mucho mayores de energía en las nuevas centrales electroatómicas que están siendo diseñadas para el Consejo Central de Electricidad.

ЕЕ ВЕЛИЧЕСТВО КОРОЛЕВА Елизавета II откроет 17 октября ядерную электростанцию Колдер Холл в Селлафильд, Камберленд. Эта станция будет первым заводом в мире, который будет снабжать государственную силовую сеть электричеством, генерируемым исключительно процессом ядерного деления. Ядерное тепло получается из двух реакторов, работающих на природном уране с графитовым замедлителем и охлаждаемых углекислотой, циркулирующей в сердечнике под давлением в 6,8 ата внутри стального сосуда высокого давления. Вокруг каждого реактора, но вне биологической защиты, размещены четыре теплообменника, в которых получается перегретый пар двух давлений: 13,6 ата (310° Ц) и 3,6 ата (171° Ц). Этим паром снабжаются четыре турбогенератора мощностью в 23 мвт, под напряжением 11,5 кв.
Завод Колдер Холл подчиняется Великобританскому Управлению Атомной Энергией. Хотя одной из его целей является производство плутония, полученный опыт приведет к значительному увеличению выхода мощности в новых электростанциях, которые конструируются для Главного Управления Электрической Энергией.

CALDER HALL

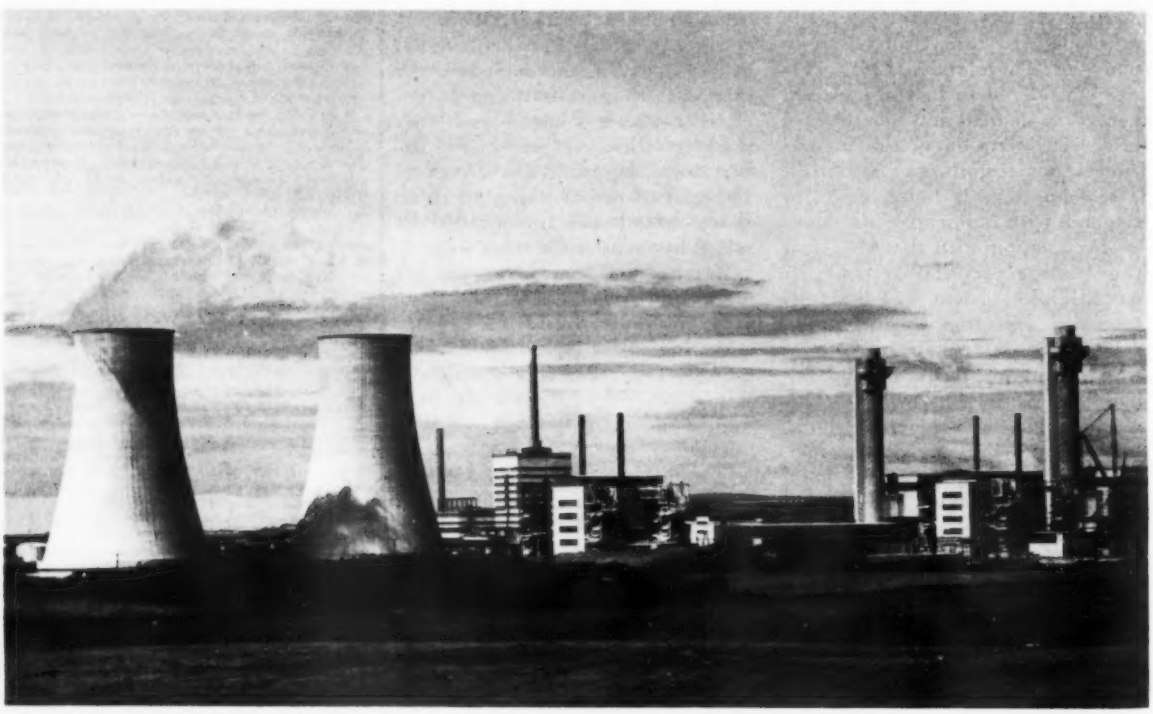
The first nuclear power station in the world
How it was built—how it works

THE BACKGROUND

CALDER HALL POWER STATION is a natural development of the two large plutonium production piles at the United Kingdom Atomic Energy Authority's Windscale Works which began working in 1950 and 1951. During 1951 and 1952 a design study was undertaken by the Industrial Group and the Research Group (Harwell) of the UKAEA for the construction of what was virtually another plutonium plant but one in which the heat generated—which is merely wasted at Windscale—is put to a useful purpose for producing electricity. At this time, the Atomic Energy Authority had not been formed and the work was under the Ministry of Supply.

In April 1952, a Plant Coordinating Committee was set up which included the Atomic Energy Department (as it then was), the British Electricity Authority (now the Central Electricity Authority), the Ministry of Works and a number of industrial firms including Babcock and Wilcox Ltd, C. A. Parsons Ltd, and Taylor Woodrow Ltd. The reasons for choosing the natural uranium, gas-cooled system have been fully justified by Sir Christopher Hinton, Sir John Cockroft and others, but briefly they may be summarized as follows:

1. The fuel had to be natural uranium because the main purpose of the plant was the production of plutonium. Additionally, sufficient enriched fuel was not available in the quantities required.
2. Graphite was virtually the only possible moderator. Light water is not possible with natural fuel and heavy water was not available.



With the Windscale plutonium factory as background, Calder Hall A is already on stream and producing electricity

Through the Grid transformers, power at 132kV goes out to the public supply system. Behind, No. 1 reactor with its exchangers is fully operational

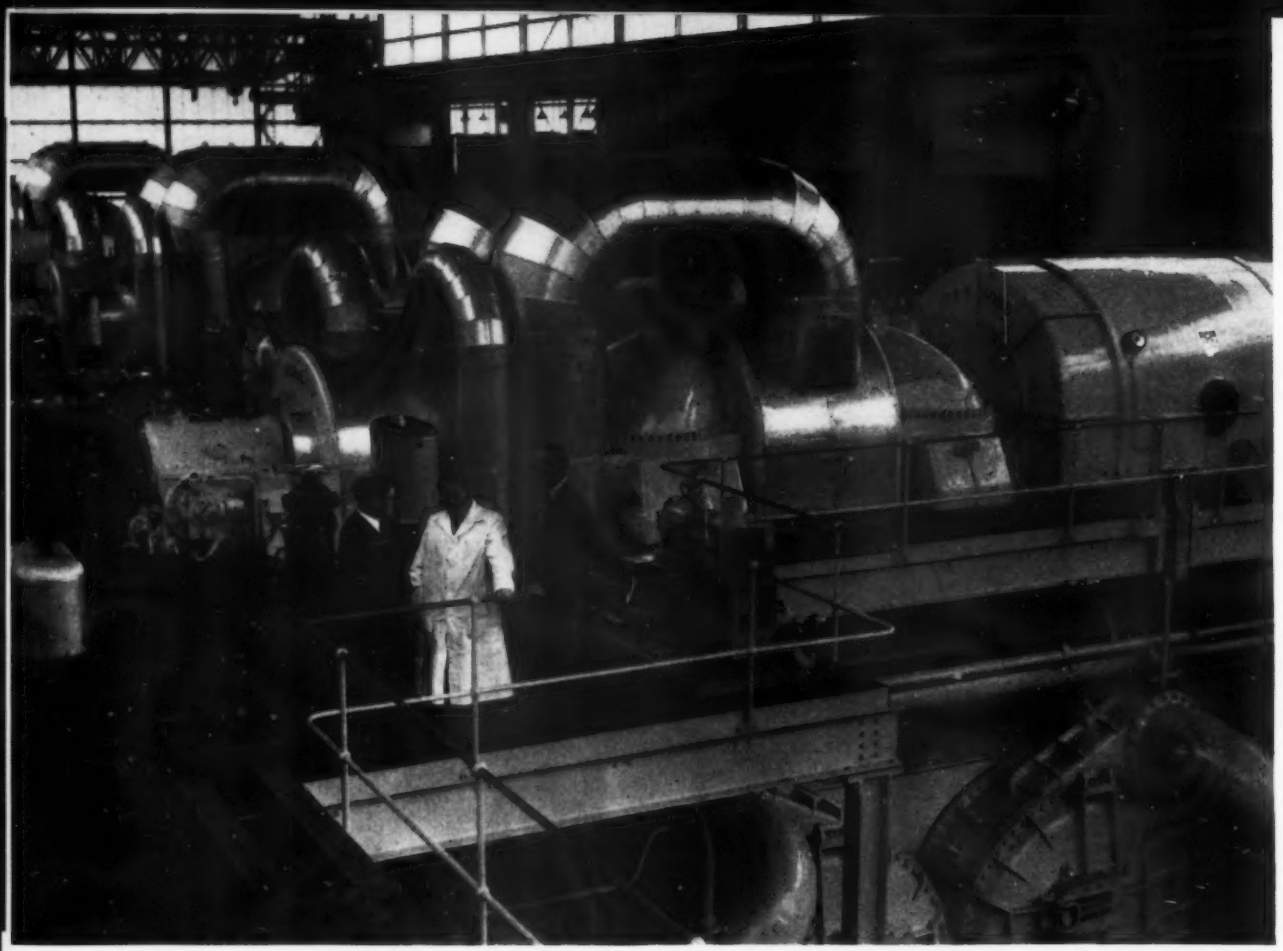
3. On the question of cooling, the choice of gas was dictated largely by safety considerations. If the coolant is a more powerful absorber of neutrons than the moderator, loss of cooling fluid leads to a rise in reactivity. Since there are no really geographically remote areas in Britain, the use of light water would have meant that the reactor would have had to be inside a containment vessel of some kind which would necessarily be very large. Gases such as carbon dioxide or helium on the other hand do not absorb neutrons and an escape of coolant would reduce the reactivity. Doubts were expressed at first about the power required for circulating the great amount of coolant required, but by pressurizing the gas, designing extended surface fuel cans and heat exchanger elements, and above all, drawing on the experience of the Windscale piles, it was considered that this problem could be overcome and that an economic, inherently safe reactor could be built. Carbon dioxide was chosen as the gas for the simple reason that ample supplies were available at low cost, factors which were not applicable the helium. The gas arrives in liquid form under pressure and is evaporated when required.

By April 1953, designs were largely finalized and a Thermal Reactor Design Office had been set up at Risley, Lancs, the headquarters of the Industrial Group. On April 30, the then Minister of Supply, Mr Duncan Sandys announced in the House of Commons that an experimental power station was to be built at Windscale and that work would begin in a few days time. The choice of site was not difficult. The land was available and since the primary product, plutonium, had to be extracted at regular intervals from the irradiated fuel elements, it was obviously convenient to have the station as near to Windscale as possible. It was therefore decided to build it on land which once belonged to Calder Hall farm, just across the river Calder from the Windscale factory. This is on the flat coastal plain between the Cumberland fells and the Irish Sea which is only about ½ mile away.

At this time the plant was known under the project name PIPPA. The basic scheme was simple: the details complicated.

Two reactors, four turbines

The reactor consists of a large graphite core inside a steel pressure vessel, the core being pierced with vertical channels for the canned natural uranium fuel



In the well-lit turbine hall, four 21MW Parsons turbo-alternators are ranged side by side. Finished in different colours these introduce a new note in power station practice

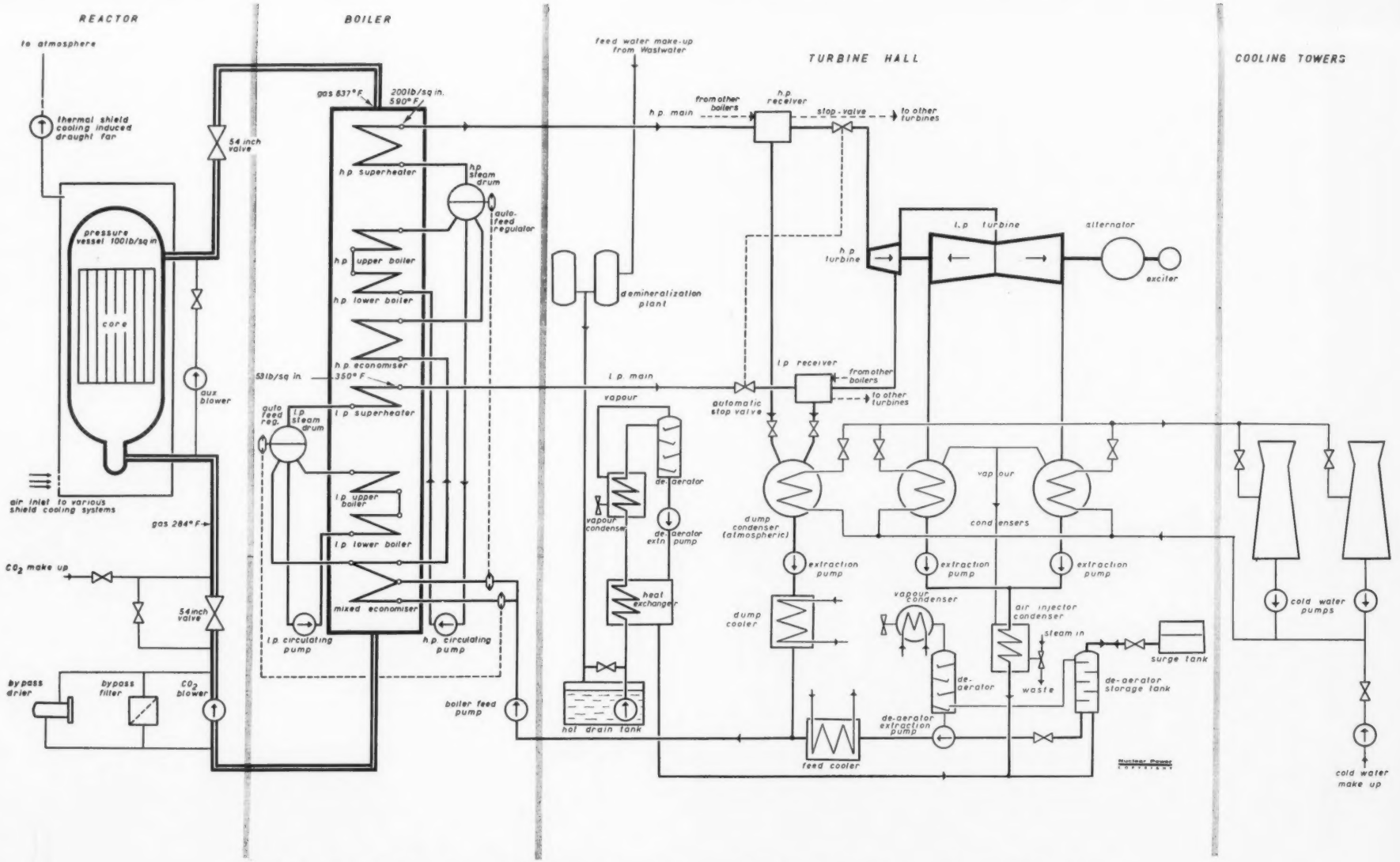
elements. Carbon dioxide under a static pressure of 100 lb/sq in. is circulated through the core by four blowers, and four hot gas outlets in the pressure vessel lead to vertical cylindrical water-tube boilers with economiser, evaporator and superheater sections. On leaving the base of the four heat exchangers, the gas returns to the blowers, the whole circuit being completely closed.

There are two complete reactors with their associated boilers situated at the opposite ends of the turbine hall. This contains four 21MW turbo alternator sets working on a dual-pressure cycle and generating at 11·5kV. This part of the plant is not unconventional but an unusual item is the provision of two dump condensers which can be used to absorb the reactor heat output when the turbines are out or on part-load. Two hyperbolic cooling towers on the station axis to the south and a grid transformer station stepping up to 132 kV complete the layout.

Vertical fuel channels

The fuel channels in the graphite core are vertical, which is a complete departure from previous British piles. This arrangement is convenient because it makes the supporting of the 1,200 tons of graphite simple and obviates any possibility of flexure in the fuel channels. It also makes the pressure shell relatively simple and facilitates the design of the gas circuits. It does, however, complicate the supporting of the fuel elements and renders very difficult their charging and discharging since they enter and leave the pressure shell through the same hole. Since some 1696 channels are in operation, it is virtually impossible to provide separate loading holes for each element and so they are grouped in batches of 16 which means that only 106 charging holes have to be provided. This, however, means that a relatively complicated mechanism for charging and discharging had to be arranged. The maximum fuel charge is 10176 elements totalling 130 tonnes of natural uranium.

The output of a nuclear reactor is determined almost entirely by the maximum permissible fuel temperature and in the case of Calder Hall, this was considered to be about 740°F. This led to a gas outlet temperature of 637°F. Having settled this, the heat recovery would depend on the mass flow of coolant and this in turn was fixed by the operating pressure. Owing to the sheer size of the core pressure vessel it was clear that it would have to be welded on site and since 2 in. was the maximum plate thickness considered practicable at the time, the working gas static pressure was fixed by this consideration at 100 lb/sq in. Using these and other data, the maximum thermal output of the reactors came to about 200MW each.



Much simplified, this schematic diagram shows the complete flow through one circuit. The plant actually has two reactors, each with four heat exchangers, and there are four turbines and two dump condensers. The reactors are normally run at full power continuously, any excess steam over turbine requirements being diverted to the dump condensers

Two-pressure steam cycle chosen

AS LONG AGO AS 1948, investigations were started to determine the optimum steam cycle for the gas-cooled graphite-moderated reactor and in the course of this, single, double and triple pressure steam cycles with and without feed heating, reheating and steam compression were studied. For the cost of only a moderate amount of additional complexity, the dual pressure cycle showed a noteworthy increase in maximum efficiency on the single-pressure cycle but even more important, the peak efficiency occurs at an appreciably lower inlet gas temperature which greatly simplifies some gas circuit problems. Furthermore, the plant is designed primarily for plutonium production and so the maximum burnup for a given fuel inventory is essential. This demands as high a temperature rise through the core as possible and since the outlet temperature from the reactor is fixed by metallurgical considerations the inlet temperature must be brought as low as possible. There is however, a limit set to this by the thermodynamic cycle and the dual pressure cycle enables the reactor inlet temperature (284°F) to be less than it would be in a single-pressure cycle.

Steam pressure control

Feed heating is not used because, if it were, the water temperature in the economiser section would be higher and so would that of the CO_2 leaving the heat exchanger. This would lead to a smaller temperature rise through the core and so for a given heat removal the mass flow would have to be increased with a consequent rise in blower power. The increased head loss due to the higher velocities would also put the blower power up. Reheating and steam compression were rejected as leading to further complexity in an already novel plant.

It was therefore decided to use a dual pressure system, the steam conditions being as follows:

High pressure steam at turbine stop valve 200 lb/sq in. abs, 590°F.

Low pressure steam at turbine stop valve 53 lb/sq in. abs, 340°F.

In the turbine, the low pressure steam is introduced at a point in the h.p. staging where the h.p. steam has expanded to the l.p. conditions ; so there is no thermal shock. Of the 257,000 lb/h mass flow per turbine, 77 per cent is raised at the high pressure and 23 per cent at the low.

Another advantage of the dual-pressure system is that it provides close control over the reactor coolant temperature and minimises temperature stresses due to load changes and fault conditions such as alternator trip-out. The l.p. supply pressure is variable through a special governor valve in the turbine hall and is arranged to be at its lowest at full load. As the load comes off the set, the l.p. steam pressure rises and the h.p. pressure falls until they are nearly equal. This has the effect of preventing the gas temperature at the reactor inlet from falling and, together with the variable speed blowers, the dual pressure cycle enables upper and lower reactor coolant temperatures to be maintained independent of load.

The building and civil engineering contract for Calder Hall was placed with Taylor Woodrow Ltd in July 1953, whose first team arrived at the site on August 4th 1953. The main civil engineering work was completed in 12 months despite unusually bad weather in the 1953-4 winter. There were at one time over 1,200 men on the job and work never fell behind schedule. Babcock and Wilcox Ltd were to handle the boilers, Whessoe Ltd, the pressure vessel and C. A. Parsons Ltd, the turbines. There were also many other contractors for specialised work.

In August 1954, the United Kingdom Atomic Energy Authority was formed and took over most of the Ministry of Supply and Ministry of Works staff who were employed on the contract.

During construction, finalisation of design details was seldom much in advance of the actual construction and closest cooperation and liaison between the many contractors and the Authority was essential at all stages and at all levels. This was done at the top level by means of monthly progress meetings.

When the Queen visits Calder Hall on October 17 one of the two reactors will be in operation and Her Majesty will operate a switch which will for the first time sent out electricity to the Central Electricity Authority's national grid. The second reactor (No. 2) is in an advanced state of construction and is due for completion in April 1957.

Three more stations building

In June 1955 it was decided that the output of plutonium from Windscale and Calder Hall would not be enough to meet current military and civil requirements. By this time, the White Paper plan (February 1955) for the ten-year programme to provide about 1,500 to 2,000 MW of electricity from nuclear power had been announced and in order to cause the minimum interference with this plan and also with the pioneering activities of the Industrial Group, it was decided that three further stations of the Calder Hall pattern should be built for the UKAEA. Accordingly, the original Calder Hall station was renamed Calder Hall A and work started alongside on one of these new stations, now called Calder Hall B. This is virtually a mirror image of the A station on the same axis except that the cooling towers are side by side instead of both along the axis. For the further two stations, there was no more room at Sellafield and a site was chosen on a disused airfield at Chapel Cross near Annan in Dumfrieshire on the Solway Firth. This had the advantage of being reasonably convenient for the Windscale processing plant. Construction of Calder Hall B and the two Chapel Cross stations started in August 1955 and completion is expected in 1958. At that time, therefore, the UKAEA will have no less than eight convertor reactors producing between them about 1,600MW in heat. The design of these further stations will to all intents and purposes be identical with that of Calder Hall A and the contractors are also largely the same. To relieve the Authority's staff from the unexpected responsibility of Chapel Cross, Merz and McLellan, the well-known consulting engineers were made responsible for the two stations.

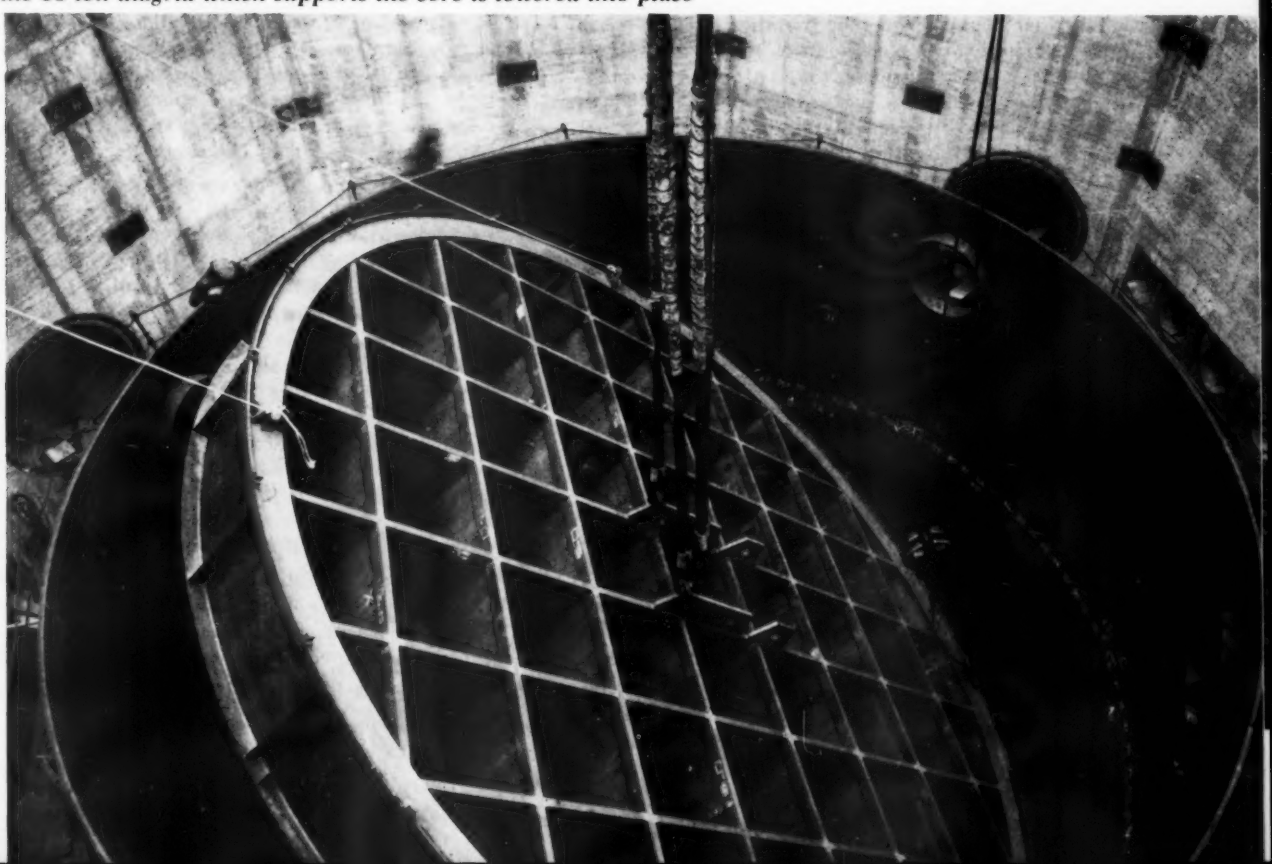
20,000 natural uranium bars plus 2,400 tons of graphite and 40 tons of CO_2 give 400 megawatts of heat

THE NUCLEAR SYSTEM

THE TWO REACTOR BUILDINGS are mirror images of each other and are constructed round the massive biological shields necessary for the reactors. Each building is 120 ft high and is supported on a concrete raft 136 ft by 107 ft by 11 ft deep and heavily reinforced in both directions. This contains 5,600 cu. yds of concrete and 270 tons of reinforcement.

The octagonal biological shield rests directly on this raft and has walls 7 ft thick, rising 90 ft from the base to the level of the charging floor. The octagonal form was chosen to minimize shrinkage effects. It is pierced on alternate faces with the four large holes for the gas outlet ducts and with numerous other small holes for the instrumentation service. The shield was poured in 20, 4½ ft lifts, laid in alternate complete bays to minimize shrinkage. Owing to the strict dimensional tolerances specified—±0·1 in. on both vertical and plan dimensions—a complete octagonal template was constructed in steel to the required standards and this was used in setting the timber formwork. Outside the octagonal shield is a further reinforced concrete envelope wall. High density concrete with a minimum value of 150 lb/cu ft was specified but, using Northumberland whinstone aggregates, the contractors, Taylor Woodrow Ltd, obtained a density of 162 lb/cu ft. A wetting agent was added to the mix which was fully vibrated. Steam-heating and calcium chloride enabled work to go on in the coldest weather. Two weighbatching

Inside the reactor pressure vessel, complete except for the top dome, the 63-ton diagrid which supports the core is lowered into place



plants and a central air flow bulk cement-handling plant were used.

The thermal shield is formed from 6 in. steel plate supplied by English Steel Forge and Engineering Corporation Ltd. These plates weigh about 3 tons each and about 500 were used in each reactor. The edges are machined to ensure a close fit and they completely line the walls, the floor and the ceiling of the reactor chamber.

Thermal shield cooling

The plating is mounted six inches from the main concrete wall and is held by vertical columns and thinner steel plates, which form a skeleton on to which the 6 in. plates are attached. Heat generated in the thermal shield is removed by passing air up between it and the cement wall by means of four centrifugal induced-draught fans mounted high up under the roof of the building. These exhaust the hot air to two 200-ft high steel stacks above the reactor building.

The fans are driven by D.C. motors supplied by two sets of rectifier equipment by British Thomson Houston Co Ltd. Each set comprises two pumpless steel-tank mercury-arc-rectifiers and one rectifier transformer with 33-position on-load tap-changing gear.

The top shield

Round the reactor shield, on suspended floors, supported on the outside by a steel structure are the various service areas such as the reactor control room, the burst-cartridge control room, fuel stores etc.

One of the most difficult parts of the construction of the reactor block was the pouring of the top concrete shield after the steel pressure tank had been assembled and set inside the shield. The top dome of the vessel has projecting upwards over one hundred vertical tubes through which fuel elements are loaded and control rods pass. Permanent steel shuttering was used for this part of the work and 8 ft of concrete was poured carefully round all the tubes since they had to be set with the utmost accuracy. The main civil engineering work on the first reactor was done in 12 months and it was entirely completed in 33 months.

Pressure vessel fixed size of whole plant

THE CORE OF EACH REACTOR is formed by a pile of pure graphite blocks (cross-section, 4 millibarns) arranged to form a right circular cylinder 27 ft high and nearly 37 ft diameter. The inner portion, with a nominal diameter of 31 ft and a height of 21 ft forms the core proper and the graphite blocks in this section are machined with 4 in. diameter holes which, when the blocks are stacked, form the fuel channels. The graphite outside the actual core volume constitutes the neutron reflector.

The fuel element channels number 1696 and are arrranged in an orthogonal lattice with a module of 8 in. For loading purposes, the lattice is considered in groups of sixteen channels (4 by 4) and each such group is accessible for charging and discharging through a 6 in. branch connecting the pressure vessel with the charge floor. In the centre of each group of sixteen a smaller hole is arranged in the praphite blocks through which the control or safety rods enter the core. At the top of the core each group of sixteen holes is capped by a square steel casting about 6 in. thick with sixteen holes matching those in the lattice. The holes in the casting taper out and their purpose is to allow the fuel elements—which are introduced obliquely to the channels through the charging chute—to slide smoothly into the selected channel without damage to the element or to the graphite.

The design problem

Below, the graphite—of which there are about 1200 tons—is supported on a massive steel structure known as the diagrid. Across the members of this component are bolted 4 in. steel baseplates which are pierced with holes coinciding with those of the lattice. These plates support the graphite through a number of roller races which permit differential expansion between the diagrid and the graphite.

During all stages of design and manufacture the contractor responsible for the pressure vessel, Whessoe Ltd of Darlington, had the following factors constantly in mind:

1. The shell had to contain carbon dioxide at a high temperature and pressure (637°F, 100 lb/in²). This meant a series of compatibility studies of various steels with the gas.
2. A load of over 1200 tons had to be supported inside the vessel and this had to be kept in a fixed position in space under all conditions.
3. A considerable degree of freedom had to be provided in view of the dimensional changes to be expected under these conditions.
4. A number of branches—one 12 ft diameter—had to be provided in the shell.

In order to economize in blower power, it is necessary to raise the pressure in the gas coolant circuit to as high a figure as possible and in the case of the Calder plant the limit was set by the thickness of steel plate which it was considered feasible to weld on site to the stringent inspection standards necessary on this job. At the time the vessel was conceived another large shell was under construction to form a pressurized vertical spinning tunnel for the National Aircraft Establishment at Bedford and although the Calder reactor tank had much more rigorous design requirements the NAE windtunnel provided valuable experience.

Thicker plate could now be welded

It was necessary to fabricate and erect the vessel on site and experience had shown that for this, a ductile mild steel with good impact properties at the low temperatures expected on site work was essential to obviate the risk of brittle fracture. Accordingly, an aluminium-killed high manganese mild steel with

The graphite core is pierced with 1696 vertical fuel channels, each group of sixteen having a central hole for a control rod. Interlocking chases on the blocks hold the pile rigidly in place. Above, a gas-outlet temporarily blanked off

a satisfactory Izod value at the temperatures to be expected was selected from the shell. At the time, plates of 2 in. thickness were considered the largest that could reasonably be welded in the field and this virtually decided the size of the whole plant. In the light of experience gained at Calder Hall, thicknesses of $3\frac{1}{2}$ or even 4 in. are now considered practical propositions.

With a thickness of 2 in., therefore, and an inside diameter of 37 ft and a height of about 60 ft with domed ellipsoidal ends, the safe working pressure was determined at 100 lb/sq in. gauge. The shell was tested to 125 lb/sq in. and five pairs of relief valves are provided in the gas circuits, set at 115 lb/sq in.

During construction, rigid quality control was maintained on all materials. Ultrasonic flaw detection equipment was used on every plate to ensure freedom from internal laminations and metallurgical spot checks were frequently performed to ensure that the steel specification was being maintained.

Five of the six sections which form the shells were fabricated on the site. These were: the bottom dome with a 12 ft branch for the inlet manifold (which arrived complete) ; two cylindrical sections, the upper of which contains four branches for the gas outlets ; the top dome containing well over a hundred 6 in. branches set to a very high degree of accuracy for the fuel element loading tubes ; and finally the diagrid. These five sections were built up at ground level from preformed plates, each one of which had full weld preparation and a trial assembly at Whessoe's Darlington works. As each section, beginning with the bottom dome, was completed it was lifted by a 150-ton derrick 200 ft high and lowered down inside the concrete shield which at this stage had been completed except for the top. Only welders who had passed the most exacting tests were used on fabrication and assembly and all butt welds were inspected along their whole length by radiography to Lloyd's Class I standards. Fillet welds were examined by crack detection techniques. The reason the shield was completed first was that as much time as possible was needed to design the pressure vessel whereas the shield was reasonably straightforward. If the shield had waited for the vessel, time would have been lost.

When the vessel was completed it was stress-relieved by an operation believed to be unique. The outside of the shell was covered with thermal insulation and an internal network of heavy gauge tubing was arranged to form a gigantic heating element inside the walls. About 1·5MW were passed through this and the whole shell brought up to over 1000°F and held there for 8 hours. This operation took several days to reach the final temperature and after the soaking period the vessel was allowed to cool slowly and evenly.

The 63-ton diagrid which supports the graphite core consists of a fabricated I-section beam shaped to form a complete circle of a diameter slightly less than that of the inside of the pressure shell. The web is stiffened at intervals and the complete ring beam is spanned in two directions at right angles by a lattice of I-beams. Forming a highly redundant structure, the stressing of this component involved the solution of a set of 35 simultaneous equations and this was done in a few days on an electronic computer at the National Physical Laboratory. The weight on the diagrid is taken by brackets directly through the shell on to ten inverted A-frames which rest on the thermal shield. The frames are loosely bolted to the brackets and the shield and the three contact surfaces of each frame are radiused. In this way the weight of the graphite is taken through the shell wall to the concrete foundations and the shell is allowed a degree of freedom for radial expansion although its centreline is fixed in space.

On completion, the whole vessel underwent a pressure test. Conventionally this would have been done hydraulically to eliminate the danger due to the large amount of energy in compressed air, but it was decided to use air in this case since the massive biological shield would provide first-class protection in the event of an explosion. Furthermore, it was considered that if water had been used—the vessel contains 57,500 cu ft—the weight might overstrain the structure. In the pneumatic test to 125 lb/in², strain gauge readings were taken at many points to confirm the calculations. The final test was under vacuum at 1/10 atmosphere and this was done by using the large rotary vacuum pump which is part of the plant and which is normally used for exhausting the vessel after fuel charging and before the carbon dioxide is refilled.

Nine-inch thermal insulation

After extensive tests by the UKAEA it was decided that the magnesia thermal insulating products of the Darlington Insulation Company Ltd possessed satisfactory characteristics to withstand exposure to radioactivity and the materials chosen were Darlington 85 per cent Magnesia and Meta-Dextramine and on most places, Darlington Armouring Compound No. 1 was also applied. On the reactor vessel, great care had to be taken to allow for expansion and contraction of the metal without damage to the insulation. Since a thickness of 9 in. was applied, special provision had to be made to support the weight of insulation on the vertical surfaces.

The stacking of the 1,200 tons of graphite blocks supplied by British Acheson Electrodes Ltd was done by AEA labour and the blocks were all brought in through the 54 in. carbon dioxide outlets. Stringent precautions were taken to ensure scrupulous cleanliness and the men worked in a completely air-conditioned atmosphere.

How fuel elements are changed

THE TOP OF THE BIOLOGICAL SHIELD forms the control and charge and discharge face of the reactor. As has already been mentioned, there are 1696 fuel channels. Each of these can contain up to six fuel elements. The fuel is in the form of 40 in. bars of natural uranium 1·15 in. diameter. They are canned in magnesium alloy sheaths, (magnox) with an inside diameter of 1·165 in. and an outside diameter of 1·30 in. The cans have a single-start helical fin of 2·125 in. dia and are closely pitched with a very small helical angle. At the lower end, the can is welded into a plain conical end while at the upper end there is a matching female end so that the elements stack one above the other. Radial clearance is maintained in the 4 in. fuel channels by means of a 3-legged spider which forms part of the upper conical fitting. The uranium is not bonded to the can but the 0·015 in. diametral clearance in the sheath is removed when the elements are under the 100 lb/in² pressure so that a good metal-to-metal contact is obtained.

Before the concrete is poured to form the top shield, fuel charging tubes are held rigidly in position and permanent shuttering is arranged between them

Serving each group of 16 channels and one control-rod hole in the centre of the 4 x 4 lattice is a steel tube branch which runs from the pressure vessel dome, through the top biological shield to the charging floor where it ends just below floor level in a flanged fitting. There are 112 of these branches. If a control rod is in use in that particular section, the control rod motor is bolted to the flange: if not, it is blanked off or an experimental facility may be attached.

The initial reactivity of the reactor is 4·0 per cent and this is controlled by 50, 2 in. diameter rods of hollow boron steel cased in stainless steel. The same rods are used for shut down and safety and are raised and lowered by stranded cables wound by drive motors (type GB27) developed specially by Metropolitan-Vickers Electrical Co Ltd. These units are completely sealed and work under the hot high-pressure gas conditions inside the charging tubes connected to the reactor vessel. The only link with the outside is an electrical connection made through a glass-to-metal seal. Sixty of these motors are supplied for each reactor, most of which are for coarse control and safety with four for fine control. With all the rods moving together, the maximum possible rate of increase in reactivity is 2×10^{-6} per cent per second. The rod motion is controlled by varying the frequency and phase sequence of the supply to the motor. For shut off, a solenoid clutch disengages the motor and the rods fall by gravity, controlled by an eddy current brake.

Reaching 16 holes through one tube

Charging and discharging are carried out using special machines running on rail tracks on the charging floor. The machines are basically similar but the discharge one is heavily shielded whereas the one for fresh fuel is not. There are two of each on each reactor. The machines carry a sheet steel 'basket' in which enough fuel elements for four channels are carried in a manner rather similar to the shells in a revolver magazine. The machines are electrically propelled. There are a total of seven equispaced rails so that twelve tracks of fuel loading tubes can be covered there being two rows of holes between each pair of rails. At one end of the tracks there is an electrically operated traverser which serves all the tracks. To change from one set of tracks to another, a machine is driven on to the short rails on the traverser which is then moved until it is opposite the new track. The machine then drives off under its own power. The machines incorporate a winch for lowering and raising the fuel cartridges, driven by a reversing motor with a wide variation in speed control from the normal operating speed of 175 ft/min down to a creep at both extremities of the motion.

The cable ends in an electrically-operated grab which automatically takes hold of the spiders on the top end of the fuel elements as soon as contact is made. Complete indication is provided on the machines on the state of the grab (open or closed), if an element is hooked, length of run out, slack cable, and magazine position. The operator rides on the machine and has the operation under finger tip control at all times. Full safety devices and interlocks are provided. This section of the plant was provided by Strachan and Henshaw Ltd, Bristol.

Calder fuel elements are canned in magnesium alloy sheaths with a close-pitch single-start fin. The spider fitting at the top locates the elements centrally in the channel

The procedure for changing fuel elements is as follows. The plant is first shut down and depressurized down to a very low level through a rotary vacuum pump discharging through the stacks. The cover plate on the charge tube is removed and a temporary valve and gland assembly fitted in its place. The heavy shield plug is then withdrawn through the gland and a long pipe wide enough to take the fuel element and known as the guide chute is lowered into the tube by the overhead crane. The temporary valve and gland are then removed, a valve on the chute preventing loss of CO_2. A purged discharge machine is now aligned over the chute and connected to it. The guide chute extends right down to the cast iron plates on top of the graphite where it is aligned over the appropriate hole by means of a selector device on the charge machine. It will be appreciated that the chute is therefore at an angle to the vertical. The grab is then lowered until an element is caught and this is then withdrawn right up into the magazine in the charge machine. The

On the loading floor, four self-propelled machines carry out the charging and discharging operations. The nearest ones are for loading fresh fuel: the farthest ones—heavily shielded—are for irradiated cartridges

grab unhooks, the magazine turns to the next empty chamber, and the grab descends for the next cartridge.

When the magazine is full, the discharge machine moves away, the chute and machine valves are closed and a loaded charge machine comes along which then proceeds to lower the fresh fuel elements.

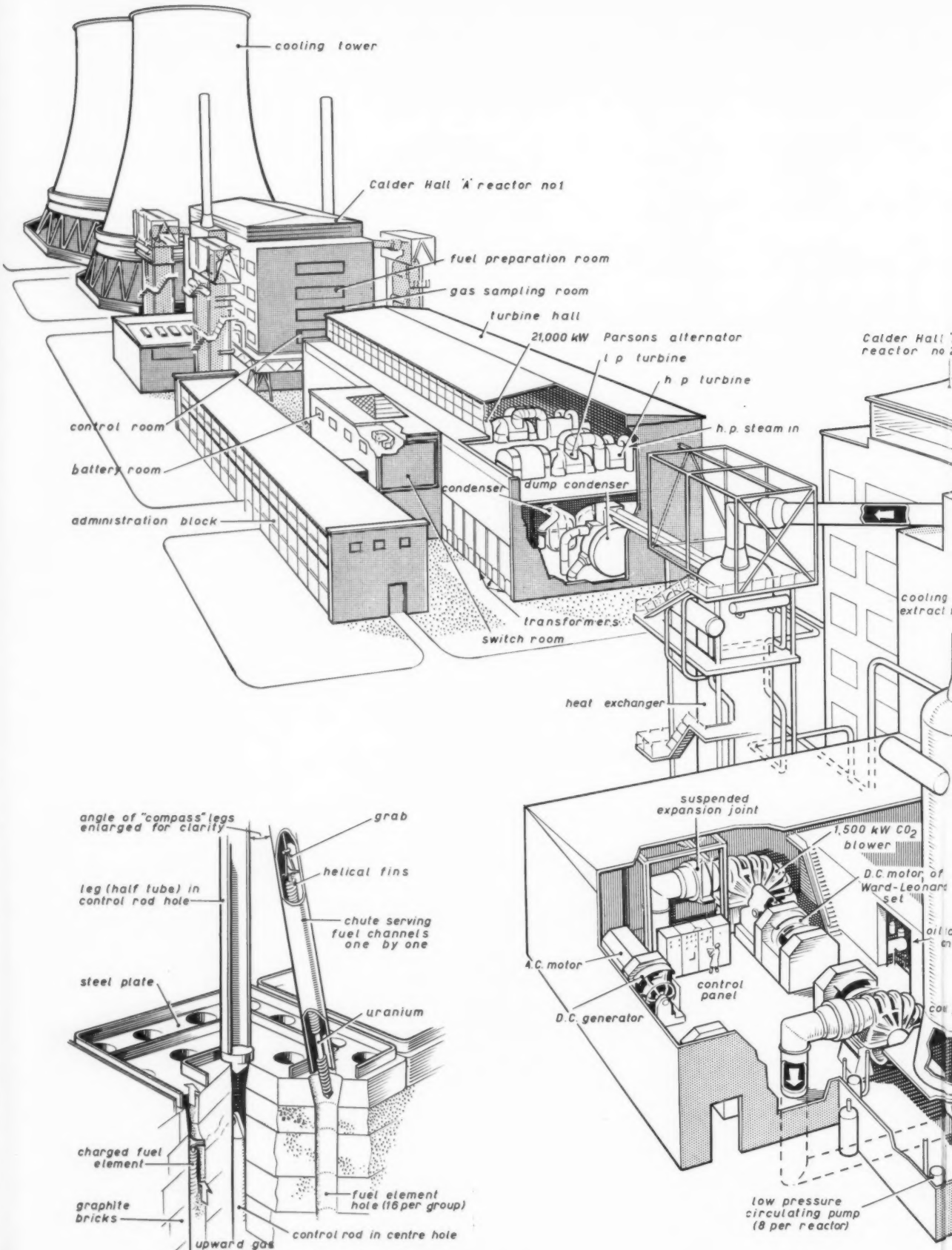
The whole area of the charging floor is commanded by an overhead travelling crane of 64 ft span having a crab with twin hoisting motions, of 7·5 and 1 ton capacity respectively. The duties of the crane comprise the handling of the charge plugs, guiding chutes, local shield boxes and maintenance of control rods and charging floor equipment generally.

For many of these purposes it is necessary for all the motions of the crane to be smoothly variable from full speed down to a creep speed, and this is achieved by adoption of Ward Leonard control.

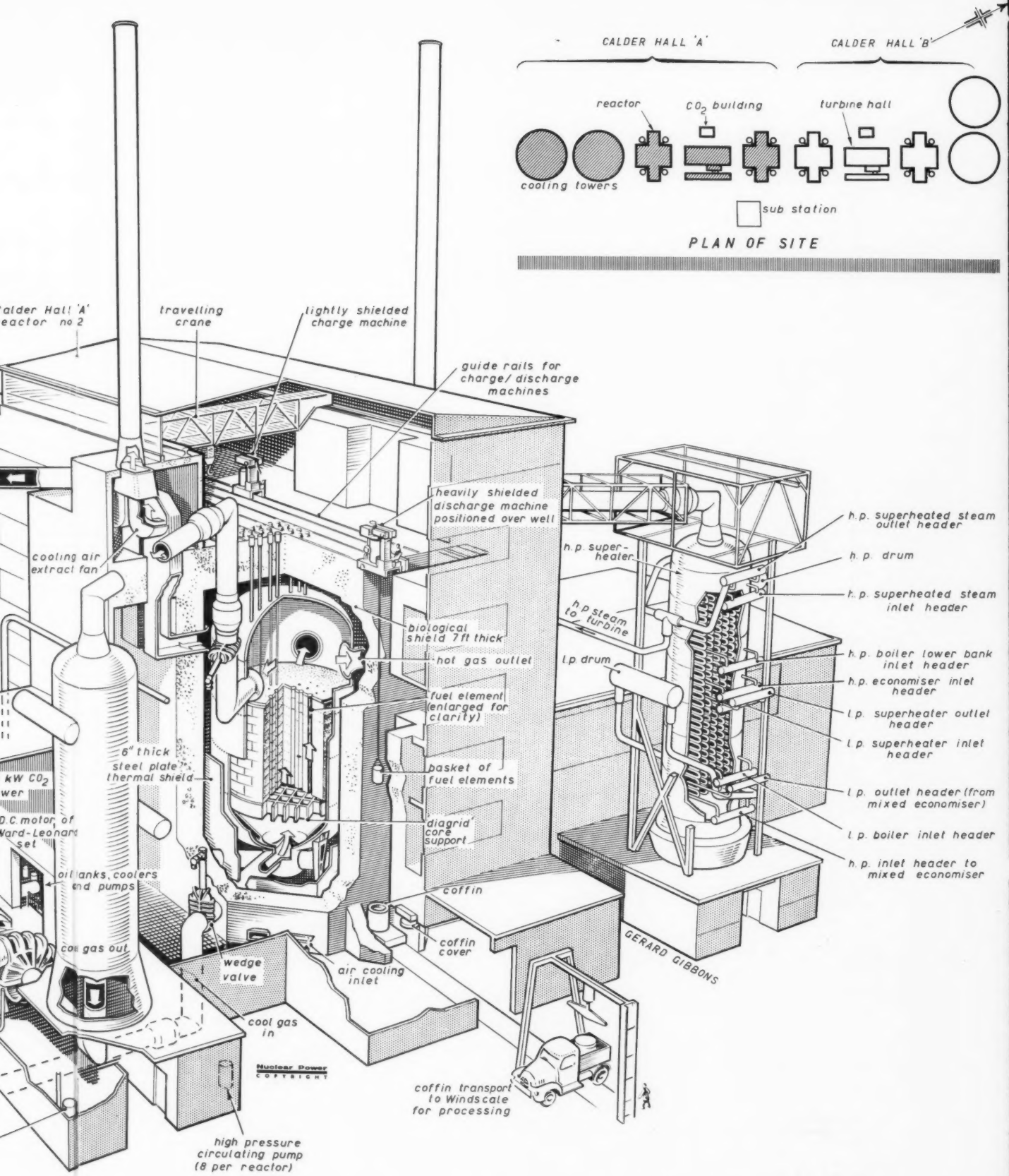
Transporting the slugs to Windscale

When a discharge machine magazine is full, the machine moves to the traverser and brought over the opening of a vertical well which runs to the ground floor of the building inside thick concrete. The hole is normally closed by a heavy sliding door but when the discharge machine is over it, it is opened and so is the heavy shielding door underneath the magazine. When ready, the complete magazine with 24 elements is lowered on a winch to ground level where it enters a heavy cast-iron coffin containing water. A lid is automatically closed on this and the coffin is moved out on rails through a heavy sliding door to a loading gantry just outside the reactor building. Here it is loaded on to a truck for transport to the adjacent Windscale Works for processing. On arrival back at the reactor building, the magazines are thoroughly dried on a roller conveyor drier before being hoisted back to the charge area.

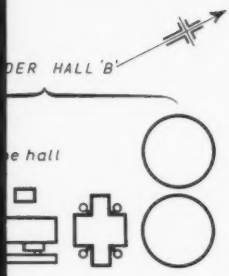
The reactor control room is situated just below the charge floor level facing the turbine hall. The gas flow system is shown on a large mimic panel with coloured lights showing the position of the main gas valves. Miniature chart recorders and intergrators keep track of the gas flow at all times and a full-size recorder on the panel shows the reactor power. The neutron flux detectors are mounted in a graphite block just outside the pressure shell.



CHARGING METHOD



Copies of this drawing may be obtained from *NUCLEAR POWER*, 3 Percy Street, London, W. 1, at a cost of 6d post free



CALDER HALL

Nuclear Power Station

Sellafield Cumberland

Opened by Queen Elizabeth II on October 17th 1956, this is the first full-scale atomic power station in the world. Two graphite-moderated reactors, each containing over 10,000 canned natural uranium fuel elements, are cooled by carbon dioxide circulated under pressure to vertical heat-exchange towers. In these, steam is generated and fed to the central turbine hall where are installed four 21,000kW turbo alternators. Electricity is generated at 11·5kV and stepped up to 132kV for supplying the Central Electricity Authority grid. Alongside, an identical station, Calder Hall B, is already under construction for the United Kingdom Atomic Energy Authority. The first stations in Britain's ten-year programme for large-scale nuclear power are based on this design but will have a much increased output.

p. superheated steam outlet header

p. drum

p. superheated steam inlet header

p. boiler lower bank inlet header

p. economiser inlet header

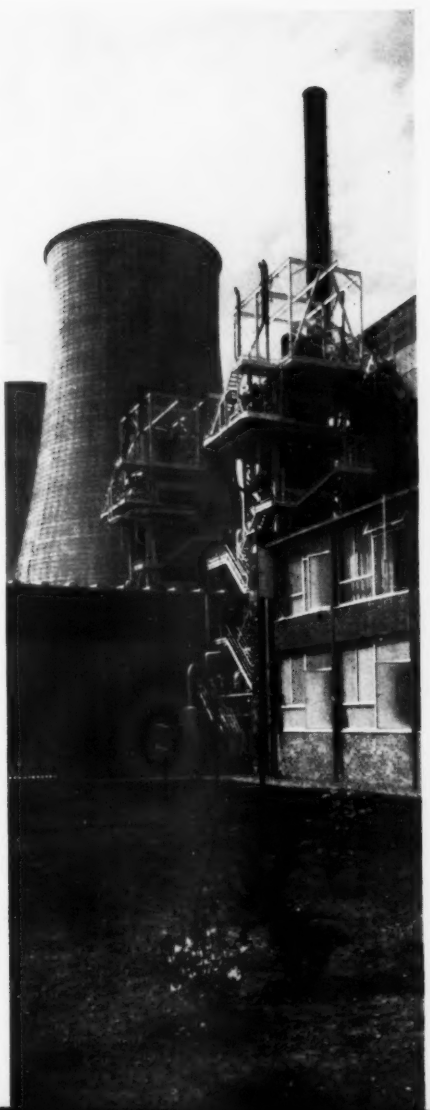
p. superheater outlet header

p. superheater inlet header

p. outlet header (from mixed economiser)

p. boiler inlet header

p. inlet header to mixed economiser



W. 1, at a cost of 6d post free

What happens if there is a burst in a fuel can

AN IMPORTANT PART of the control system is the burst fuel cartridge detection gear and a complete control room is given over to this. The system is based on that already in use at the large plutonium producing piles at the Windscale works although major changes have been incorporated to satisfy the somewhat different requirements. This part of the plant was equipped by The Plessey Co Ltd of Ilford.

Normally the activity of the coolant gas is very low indeed but if a fuel sheath becomes punctured, fission products and uranium oxides are able to enter the system. Every single fuel channel has a sampling hole connected to it by means of which the gas in that channel can be tested for activity. The system will not locate the actual fuel element which is leaking but it narrows the search down to those in a particular channel.

Eight bundles of 212 pipes in banks of four lead through the pressure shell and the shields to 53-way selector valves which enable a single bank in each bundle to be chosen for test. In order to prevent long-life uranium oxide contaminating the whole detection system, the gas sample is first cooled and then filtered. Some of the fission products are gases so that they can easily pass through the filter, but they soon decay to solid particles and it is on these that the test is made. This is done by precipitating them electrostatically on to a thin moving wire which is continually monitored for activity in such a way that extraneous effects are eliminated and the count is accurately representative of the size of the burst.

Locating the right channel

There are eight of these precipitator units working on the fuel channels, with four others for sampling gas from other parts of the circuit and to act as spares. Each unit consists of a horizontal cylindrical casting comprising precipitator chamber, counter and wire-driving mechanism. Access to the interior is obtained through a heavy pressure-tight door at one end and the casting also provides shielding for the counting equipment. The precipitators are mounted on welded steel frameworks which also contain the EHT supply unit for the precipitator, ratemeter, control unit and fault alarm system. Warnings are given visually of: EHT failure; gas flow, and temperature; wire drive and wire breakage; and gas leakage through the drive seal.

For presentation of the vast amount of information coming from the 1696 fuel channels, eight 54-point Elliott Scanning Recorders, type ND 57, are installed in the main control room. A full description of this instrument is given elsewhere in this issue but in effect it is basically a standard self-balancing potentiometric recorder modified so that 54 miniature records are produced simultaneously. The chart moves $1\frac{1}{2}$ in. in 24 hours and the records are $1\frac{1}{2}$ in. wide. The activity count from a particular group of four channels is shown by the horizontal trace from the column zero. When any abnormality is recorded, alarm bells ring and the signal may be switched to a full-scale recorder for further investigation. The outputs from the group of four suspect channels are then switched individually in turn to a spare precipitator and the particular faulty channel is then identified.

Can bursts of about 1 mm diameter can readily be detected by this equipment. At the operating temperature, the CO_2—U reaction is not severe and several hours are available before a faulty element must be removed. Naturally, since there are up to six cartridges in each channel, all six must be removed since the precise one cannot be identified by the system.

Gas from the fuel channels is continuously filtered and tested for activity, the whole 1696 being sampled every half-hour. Stainless-steel tubing—45 miles of it—lead from the reactor to the special control room where any solid fission products are electrostatically precipitated onto a moving wire which is constantly monitored. Awaiting completion, tube ends are here sealed

18 acres of extended surface raise one megapound of steam an hour for Calder's turbines

THE HEAT EXCHANGE SYSTEM

THE FOUR HEAT EXCHANGER COLUMNS or boilers, situated at the corners of each reactor building are 1 5/16 in. steel shells, 18 ft diameter and about 70 ft high. From the reactor pressure vessel the hot gas is carried through the thermal and biological shields in 54 in. mild steel pipes to the centre of the top dome of the exchangers. At the bottom, it leaves through the bottom dome and passes back via the gas blowers to the inlet manifold at the base of the reactor vessel. The boilers complete each weigh about 450 tons and to avoid any risk of cracking or unsettling the reactor raft, they are mounted on separate concrete rafts.

In considering the design of the heat exchanger it is evident that, owing to the very small temperature difference between the gas and the steam—at the top end, the gas is at 637°F, while the steam temperature is about 600°F—a very great deal of surface would have to be provided, and this without excessive head loss in the flowing gas. At Calder, the choice was largely dictated by the time factor for it was considered impracticable to develop in the time available an ideal extended-surface tube which could be manufactured on the scale required. Babcock and Wilcox Ltd, who were responsible for the heat exchanger contract, therefore proposed a type of stud-welded tube of a kind which they had been using in marine work for many years and for which adequate automatic flash welding capacity was available at their Renfrew works. The studs themselves are approximately elliptical in section and about $\frac{1}{2}$ in. wide across the major axis and 1 in. high. They are welded on to the 2 in. o.d. tubes in eight rows with about $\frac{1}{2}$ in. axial spacing between the studs and provide about a fourfold increase in surface over the bare tube. Over 120 million of these studs went into the eight heat exchangers of the Calder Hall A station. Plain tubing is used in the superheater sections.

The extended surface tubing is made up into flat multi-loop elements, the inlet and outlet being at the same side. The multi-loop arrangement was chosen to give the maximum degree of flexibility and freedom from thermal stress. The elements are placed vertically side-by-side but in some sections they are staggered up and down. Each boiler comprises eight distinct sections. Starting at the bottom, there is a mixed economizer section from which the l.p. water

The four vertical boilers comprise separate economizer, evaporator and superheater sections. Here, a fitter assembles sections of the stud-tube elements inside the shell

goes up to the l.p. drum. After passing through the circulation pumps the water re-enters the shell and passes through two evaporating sections and so back to the drum. The l.p. drum is about halfway up the heat exchanger tower and is 4 ft diameter and 18 ft long. It is fitted with standard Babcock cyclones and scrubbers. On leaving the drum, steam re-enters the shell for the last time to the l.p. superheater section and so through the l.p. main to the turbine hall.

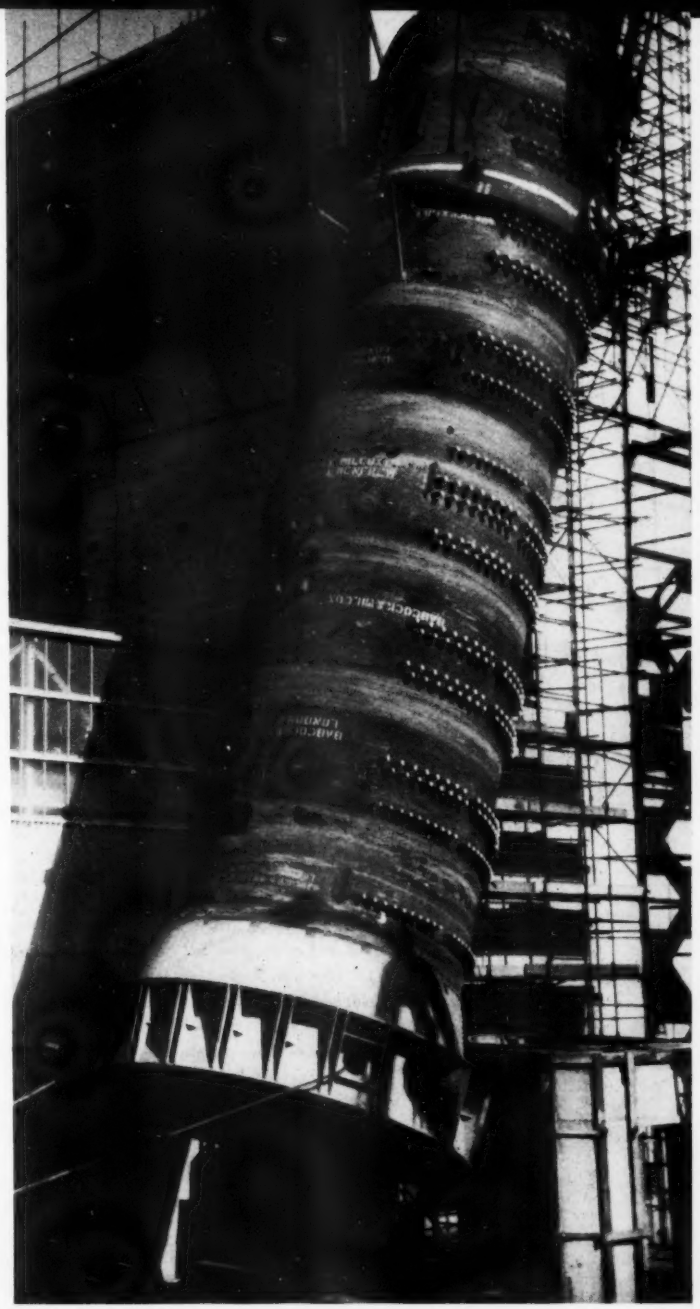
High pressure water from the mixed economizer is taken directly up to an h.p. economizer situated above the l.p. superheater. From here it passes up to the h.p. drum—similar to the l.p. one, but near the top of the tower—through the h.p. circulating pump in the basement pumphouse and then up to the two h.p. evaporating sections and out again to the drum. It finally passes through the h.p. superheater section at the very top of the tower and so to the turbines. The h.p. and l.p. mains are carried from the reactor building to the turbine hall along pipe bridges at about first-floor level.

Heating surfaces—total 99,985 sq ft per boiler

section	*no of elements in parallel*	*heating surface exposed to live gas in sq ft*
h.p. superheater	64 (plain tubes)	4,700
h.p. evaporator	64 (stud tubes)	31,500
h.p. economiser	42 (stud tubes)	15,750
l.p. superheater	32 (plain tubes)	785
l.p. evaporator	64 (stud tubes)	31,500
mixed economiser	42 (stud tubes)	15,750

Owing to the dangerous condition which could occur if water got into the reactor core, the heat exchangers were designed so that this contingency is extremely unlikely. There are no site-welded tube connections anywhere inside the pressure shell—any welds inside were done in the works and rigorously tested under high vacuum in a hydrogen atmosphere to ensure that no weld porosity whatsoever exists. Where pipes pass through the shell they do so through a previously-welded sleeve in the wall and the weld connection to headers and other piping is outside thus ensuring that a steam leak will be to atmosphere. The procedure to be adopted in the remote possibility of a leak inside the shell is as follows. The particular boiler is located immediately by an indication on the humidity indicator in the control room, connected to the gas outlet from the boiler. After isolating and emptying this boiler, gas sampling probes will be used to find the particular element which will then be sealed off outside the shell, leaving it idle when the exchanger is put back into service. The gas temperatures are so low that overheating of the idle element is not expected.

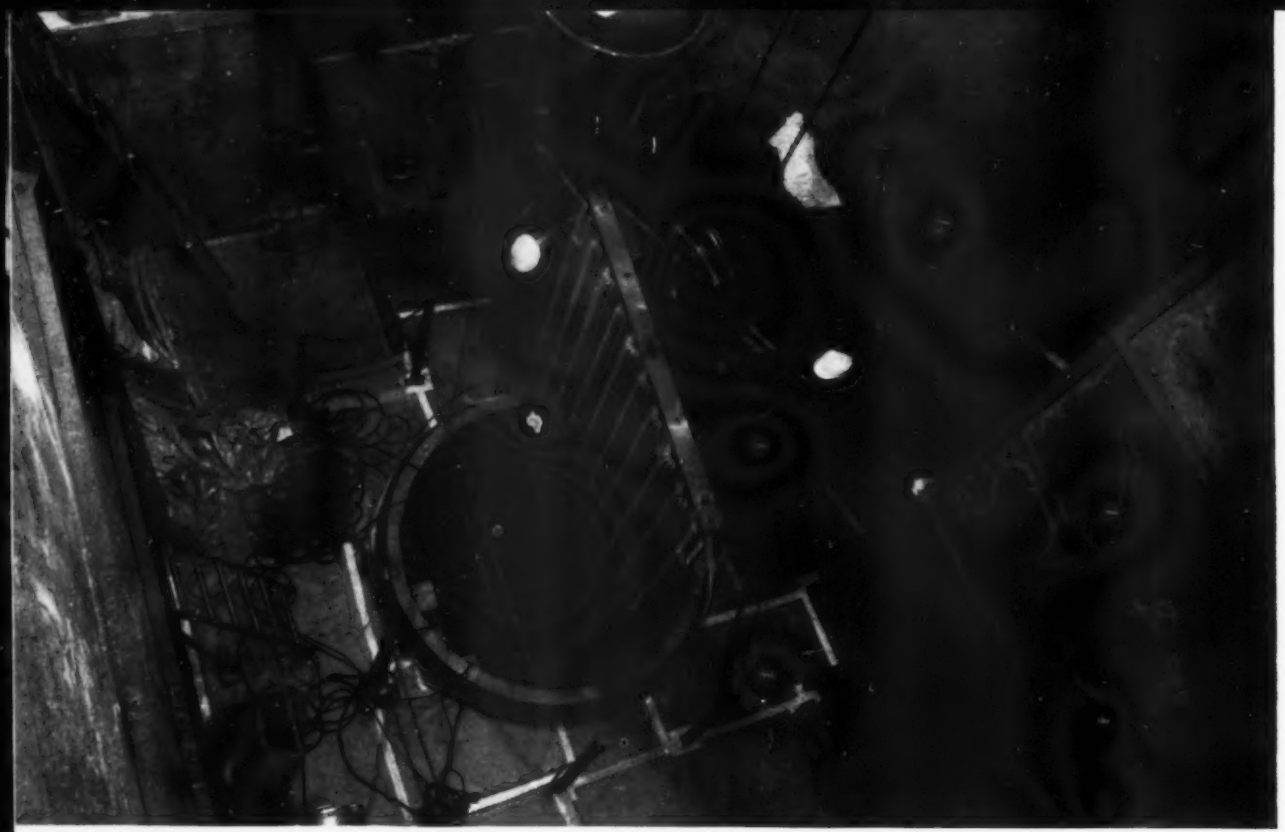
The diameter of the shells was determined by transport considerations since it was proposed to fabricate the shell in sections at the Renfrew works and take them by road to the site. The shell is of mild steel 1 5/16 in. thick and each unit is built up from six completed fusion-welded rings, a pair of semi-ellipsoidal ends, and a supporting skirt in two halves. All nozzles and branches were welded and stress-relieved at the works. At the site, the shells were



One of the trickiest operations in the whole undertaking was the lifting of the boilers on to their concrete bases. Through the welded branches on the shell will come the heater element ends to headers and drums.

assembled horizontally on special rigs which enabled them to be rotated, thus permitting down-hand welding of the seams. Stress relieving was carried out by induction heating, and full radiographic inspection facilities were available on the site. On completion, a hydraulic test was carried out with the shells still horizontal and after this they were dried, cleaned to a very high standard and sealed, silica gel being left inside to absorb any residual moisture.

After assembly of the complete shells, their erection on the prepared site was carried out by the Constructional Division of Costain-John Brown Ltd.



Ace

Inside the temporary enclosure on top of a boiler, a heat exchanger element is lowered through the gas entry branch into the shell

The vessels, which weigh just under 200 tons without the tubing had to be lifted into the vertical position and placed on 16 ft high concrete plinths to an accuracy of $\frac{1}{8}$ in. Considerable planning was needed prior to the operation and every piece of equipment was tested before operations began.

At the assembly site, which was about a quarter of a mile from the reactor building, the vessels were jacked up 4 ft from the cradles on which they had been tested and lowered on to a timber cribbing unit built to roll the vessel on to a series of dwarf walls for temporary storage. While on the walls, each vessel was orientated by spinning it on greased chocks. It took eight days from the first jacking up to arrival of the boiler at the erection site. After transportation by two four-axle bogies, the vessel was manoeuvred to line up with two 102 ft high gin-poles, the hoisting wires of which were wound by three powerful diesel-engined winches. A crane was also necessary and, because the driver was unsighted during the operations, walkie-talkie radios were installed at each winch and in the crane-drivers cab to ensure complete cooperation.

A standing way of 12 in. by 12 in. timber was built lengthways under the vessel, the bottom end of which was rested on a timber sledge which was greased on its lower side to help it slide along the standing way as the vessel was moved forward. A 30-ton 'deadman' was set behind the vessel to act as a check while the vessel was moving forward towards the plinth. This operation was controlled by an 802 Lima crane which moved slowly along the road slackening the tackle. All equipment was checked before the lift.

When the vessel was fully suspended, the end, on which the 25 ft diameter skirt ring was already fitted, was held clear of the foundations until it was above the surface of the base. It was then slacked in so that it hung suspended above the bolt holes. The foundation bolts were then inserted and the vessel lowered and bolted down.

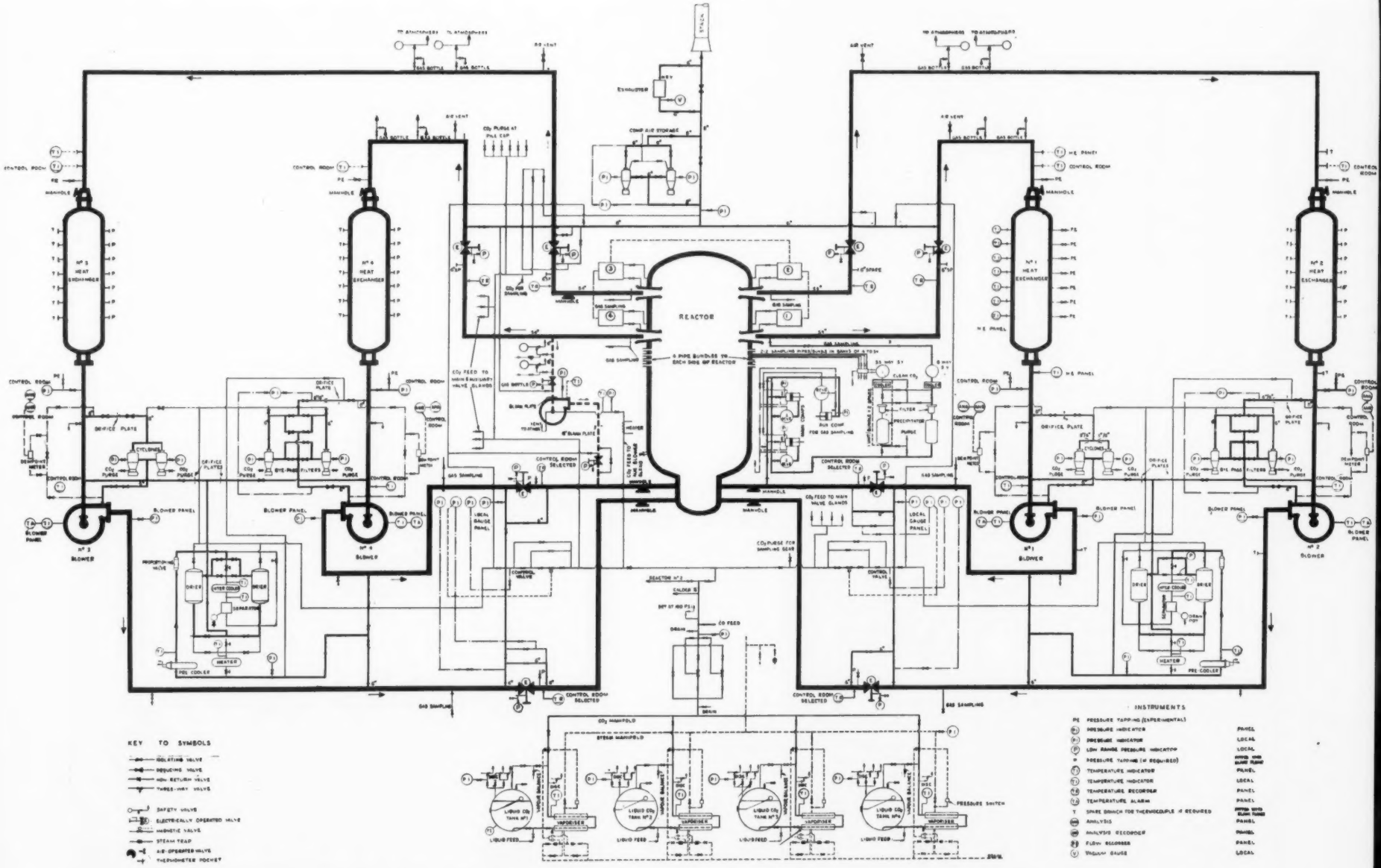
Though it took 22 days from arrival at erection site to the final dismantling of the poles, the actual lift was carried out within two hours.

Through the air lock

Once in position, the tube elements had to be fitted and this required the most stringent precautions, for any trace of mill-scale, loose weld metal or even atmospheric dust had to be removed or it would have contributed an additional source of neutron absorption in the pile.

A temporary building was erected on the top of the exchanger and an air-lock chamber was fitted to the 60 in. gas inlet branch in the top dome through which men and all components had to pass. This dimension determined the maximum size of the tube element banks. A shot-blasting cubicle was arranged above the tower and every element was thoroughly cleaned before lowering through the air-lock into the vessel, the atmosphere within being kept at a very high standard by means of a silica-gel air-conditioning plant.

On completion, the heat exchangers were lagged externally with Darlington 85 per cent Magnesia and Meta-Dextramite, Darlington Armouring Compound No. 1 also being applied extensively.



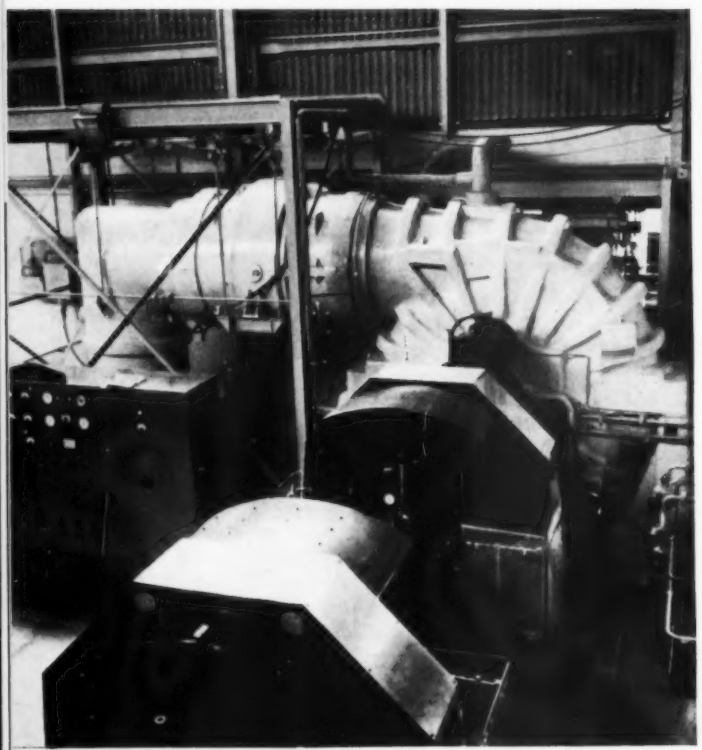
The Calder gas flow diagram. Bypass filters, drier units, gas sampling gear and carbon dioxide make-up plant are only additions to a basically simple scheme

10-to-1 speed control on gas blowers

THERE ARE TWO carbon dioxide blower houses for each reactor, each containing two blowers. The blower houses form single-storey buildings set between the heat exchangers on the east and west sides of the reactor building. The blowers, by C. A. Parsons Ltd, are of the single-stage centrifugal type driven by Mather and Platt 1,500kW D.C. motors through reduction gearing. The cast steel casings are heavily ribbed in both directions. The full load mass flow is 1964 lb/sec with inlet conditions 100 lb/in² abs and 284°F, but under start-up and part-load conditions a large variation in output is necessary—sometimes for long periods. For this reason, Ward-Leonard control system was employed with a separate Mather and Platt AC/DC set for each blower unit. A speed range of 10:1 on the blower is possible but it is considered that future developments of this type of plant may not need such a wide range. The speed of the circulators is synchronised and all four sets are controlled in a single operation in the reactor control room.

An overhung impeller was adopted for the blowers since, although the CO_2 does not become appreciably radioactive, the possibility of a burst fuel cartridge made it imperative to contain the gas at all times and a single gas seal obviously was better than two. The speed of the seal surfaces made necessary a "wet" type and provision had to be made so that the seal oil did not leak into the system either directly or by diffusion.

Parsons already had experience of similar seals used in hydrogen-cooled alternators and a modified version of this was adopted. These seals may be inspected or even removed while the system is under pressure. A standstill seal is situated between the impeller and the main seal and, when this is brought into operation, the blower can be turned at very low speed by means of a pony motor geared to the impeller shaft. A Fluidrive, type SS, clutch is incorporated in the gear train to ensure that the pony motor is not driven by the main motor.



A system of constant-support hangers support a 54-in. bellows expansion joint at the outlet from one of the eight carbon dioxide blowers

Taking care of pipe movements

The gas ductwork required very careful design to compensate for the high degree of thermal expansion to be catered for, and bellows expansion joints were adopted. Because of the size (54 in), and the pressure (100 lb/in²), these are of the tied type, a single hanger type being used for places in which uniplanar deflexions are encountered and a special gimbal ring type where angular movements are required in two planes. After considerable development work by Parsons, the final design consisted of two heavy flanges connected by plain rings to the bellows section proper and outlet casings housing the hinge pins spigoted to the bellows flanges.

Each length of duct, each valve and each bellows unit is individually supported on spring-type constant support hangers and owing to the great weight of the components some of these had to be specially designed and manufactured for the job.

In the ducts, Blakeborough motorised wedge-gate valves are fitted in each hot and cold duct and the bends have flow cascades to reduce head losses. To remove any heat generated when the plant is completely shut down, there is an auxiliary blower circuit in one of the four heat exchange branches. This continues to circulate gas when both main valves are shut, and provides sufficient cooling under no-load conditions.

To maintain gas purity and remove any contaminated graphite or iron oxide dust, about 2 per cent of the mass flow in each circuit is taken from the discharge, filtered and returned to the blower suction side. At present two circuits are using cyclone dust collectors and two, fabric filters, with a view to determining their relative effectiveness. To maintain the water content of the gas at a low value, two alumina drying units are used to hold the dew point to a fixed value. Each of these serves two gas circuits and by-pass a proportion of gas from the pressure to the suction side of the blowers.

About 20 tons of carbon dioxide are needed to fill each reactor. This arrives at the station in liquid form and is stored in four pressure tanks in a special building to the west of the turbine hall. Steam heated evaporators fed from the turbine steam mains, supply make-up gas to the gas circuit through the drying units. This plant will also supply CO_2 to Calder Hall B and was built by The Carbon Dioxide Co.

Already British nuclear power challenges coal stations —and Calder Hall is only a start

THE PERFORMANCE AND ECONOMICS

IN CONSIDERING the nuclear and thermodynamic performance of Calder Hall it must be borne in mind that it is a dual-purpose station and is not optimised for power production. Furthermore, since its inception, considerable progress had been made—particularly in metallurgical problems—which will enable the output of stations based on this design to be at least doubled with no great increase in size.

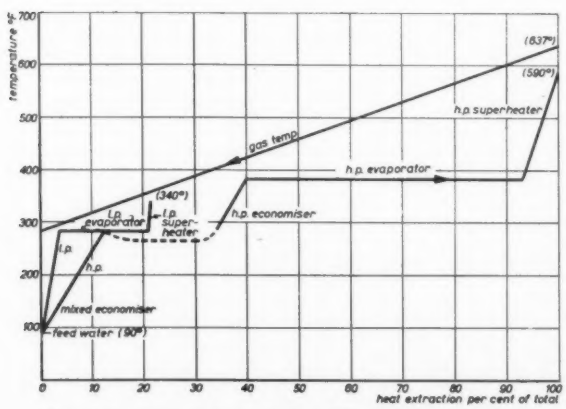
It is not possible here to give a complete analysis of the plant since all the relevant data have not yet been made public but nevertheless, using what information has been disclosed, it is possible to obtain a reasonable estimate of the likely performance.

The Fuel Charge

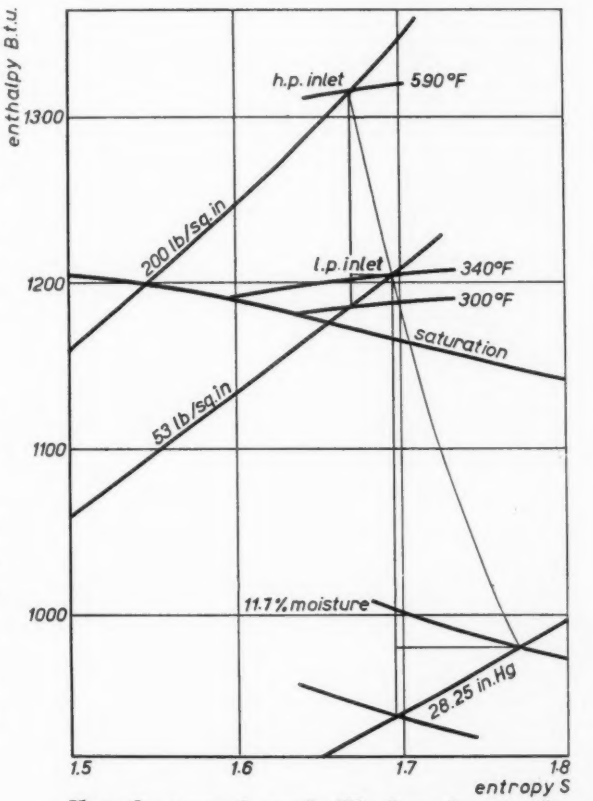
The lattice core is based on an orthogonal lattice with an equivalent bounding diameter of 31 ft. Since there are 1696 fuel channels, the lattice spacing can be shown to be 8 in.

The natural uranium bars are 1·15 in. diameter, 40 in. long and with a density of 0·676 lb/cu in. The weight of a single rod is therefore 28·1 lb. The core is given as 21 ft high, so there could be up to six, elements in each of the 1696 channels. The maximum possible load of fuel is therefore 130 tonnes (metric), made up of 10176 fuel elements.

It is understood that the initial unpoisoned critical mass is obtained with about 30 per cent of the fuel loaded. This is about 40 tonnes, which agrees well with similar piles.



How the steam is raised. The temperature difference between gas and steam is very small at certain points



How the steam is used. The heat drop in the low pressure section is about twice that in the high pressure stages

The dual-pressure steam cycle may conveniently be illustrated by means of a diagram in which temperature is plotted against heat duty percentage. The total steam mass flow per reactor of 514,600 lb/h is apportioned as 77 per cent high pressure steam at 200 lb/sq in. abs and 23 per cent low pressure steam at 53 lb/sq in. abs. It will be noticed that the same proportions apply roughly to the heat duty.

The steam working cycle may be shown on the enthalpy-entropy Mollier diagram. It should be noted that the expansion takes place in two stages but they do not correspond to the two cylinders of the turbine. In the first stage, 77 per cent of the steam expands down to the 15th stage in the h.p. casing where it is joined by the l.p. steam. The whole 100 per cent now expand to the end of the h.p. turbine and then

transfer to the l.p. machine where expansion is completed down to the condenser vacuum. Thermodynamically, however, it is convenient to regard the expansion as taking place in two simple stages.

At the h.p. stop valve, the steam has a superheat of 208°F and an enthalpy of 1316 Btu/lb. Dropping an isentropic to the l.p. stop-valve pressure of 53 lb/sq in. and assuming a stage efficiency of 83 per cent, brings the h.p. temperature to 340°F, which corresponds exactly to the l.p. entrance temperature. The enthalpy at this point is 1204 Btu/lb. Repeating the same process in the l.p. section down to the condenser vacuum of 28.25 in., with the same stage efficiency, leaves the exhaust steam 88.3 per cent dry with an enthalpy of 977 Btu/lb.

The heat drops are therefore:

1. $1316 - 1204 = 112$ Btu
2. $1204 - 977 = 227$ Btu

The condenser saturation temperature is 96° so it would not be unreasonable to assume a feed temperature at the boiler of 90° (sensible heat, 58 B.t.u.).

The thermal efficiency is therefore:

$$\frac{\cdot 77 \times 112 + 1 \cdot 00 \times 227}{\cdot 77 \times 1316 + \cdot 23 \times 1204 - 58} = \frac{313}{1233} = 25 \cdot 4 \text{ per cent}$$

The gross output, per set, neglecting mechanical and electrical efficiencies is:

$$\frac{257{,}300 \times 313 \times 778 \times \cdot 746}{60 \times 33000} = 23 \cdot 6\text{MW}$$

which, taking account of the mechanical and electrical efficiences agrees well with the stated normal output of 21MW.

Ancillaries

Gas Blowers

The circulators are of 1,500kW each and, in effect, there are two to each turbine so that they account for 14·3 per cent of the gross output. Possibly it is more, for it is uncertain as to whether efficiences of the motor and Ward-Leonard control set are included.

Circulating Pumps

These are both h.p. and l.p. forced circulation pumps for the boilers and four times the mass flow of steam is circulated. They probably account for less than 1 per cent of the output.

Cooling water pumps

Four of these are normally in operation and the power has been stated to be 640 h.p. Assuming a motor-efficiency of 75 per cent, the total power required is about 2,500kW, which is about 3 per cent of the total output.

In addition there are many other demands for power, most of which, however, are relatively small and it seems that of the total normal output of 84MW, about 20 per cent of this, or say 16 or 17MW are required for essential ancillaries, leaving approximately 67MW for disposal.

Heat rating of reactor

With 23·6MW equipment to each turbine and 25·4 per cent thermal efficiency it is seen that the reactor output must be at least 186MW and since no account has been taken of the efficiency of the heat exchangers it is clear that 200MW must be the minimum rating: it is possibly about 220-230.

Assuming 200MW, however, the load of 130 tonnes of fuel is producing 1·54MW/t. In this connection, Sir Christopher Hinton in his James Clayton lecture of 1954 said of this type of reactor 'heat ratings would be quite modest, probably in the range between 1 and 2MW per ton of uranium'. More recently, Sir John Cockcroft (NUCLEAR POWER p. 200, September 1956) said that heat extraction rates of about 3MW per ton are expected to be achieved in the future.

Neutron Flux

Knowing the power rating and the fuel load, an approximate formula, $\varphi = 3 \times 10^{12} \times (\text{MW/t})$, gives the average neutron flux as $0 \cdot 46 \times 10^{13}$ n/cm²/sec.

Fuel Consumption

Approximately, 1 gm of U235 fissioned gives 1 megawatt-day, so that at 200MW output, the fuel consumption is 200 gm/d. assuming 100 per cent load factor. But since the plant has to be shut down for charging and discharging—and there are other reasons—the load factor over a period is unlikely to exceed about ·8. Therefore, the fuel consumption over a period is more likely to be 160 gm/d or 320 gm/d for the whole station when it is complete.

According to Sir John Cockcroft (*loc. cit. sup.*) the conversion factor for this type of reactor is likely to be about 0·85 so that the rate of plutonium production from the station is possibly 270 gm/d although it is unlikely that all of this will be economically recoverable.

The burnup obtainable before fuel elements have to be changed has not of course been determined yet but Sir John Cockcroft has put it as 'at least 3000 megawatt days per ton'—or the equivalent of 10,000 tons of coal.

The economics of the type of plant were fully discussed by J. A. Jukes, Economic adviser to the AEA (Geneva paper P/390). Taking a station of 150MW output working at an 80 per cent. load factor and makinf no allowance for plutonium, he estimates a generating cost of 0·76 pence per kWh (9 millibucks). If due allowance is made for the plutonium, the figure should be between 0·59 and 0·42 pence per kWh (7 to 5 mills).

Unless otherwise mentioned, all photographs are by the UKAEA

This description of Calder Hall power station will be continued in next month's NUCLEAR POWER, which will also contain a full description of the opening by Her Majesty the Queen

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Owing to pressure on space in this issue, the 6th instalment of James F. Hill's series on Basic Reactor Physics has had to be held over. It will appear in next month's NUCLEAR POWER

Boiler circulation pumps need no maintenance

More than ten years ago Hayward Tyler & Co Ltd began to develop a glandless electric pump and motor unit from the experience the company had gained in the manufacture of submersible electric borehole pumps. The first unit was installed for circulation duties on the company's own Lamont boiler, and proved so successful that the idea has since been developed to cover the pumping of dangerous or expensive liquids as well as liquids in high pressure systems.

Since both pump and motor are contained in a pressure shell, leakage to atmosphere is effectively prevented. No rotating seals of any kind are employed. The unit therefore finds a ready application in the field of nuclear energy.

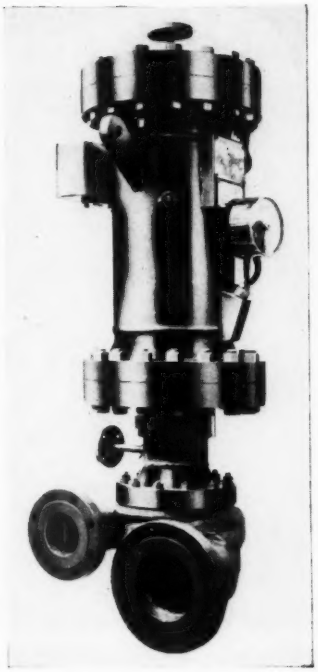
The particular application at Calder Hall is the circulation water through the secondary heat transfer circuits, and, for this purpose, thirty-four Hayward Tyler glandless pumps are being supplied to the order of Babcock and Wilcox Ltd.

Apart from the absence of leakage, these pumps have several other features. The inclusion of both pump and motor in a rigid pressure shell, mounted in a vertical position, eliminates problems of alignment. No baseplate is necessary, since the whole unit can be suspended from above or carried by supporting the suction and discharge flanges.

When the pump is at rest the pressure on both ends of the shaft is equal and thus, when starting, there is no thrust bearing drag to overcome.

Both thrust and journal bearings are of the tilting-pad type employing respectively a disc and sleeves of plastic material running against stainless steel pads. These bearings are water lubricated and require no attention whatever, and it is this feature, coupled with the absence of stuffing boxes, which allows Hayward Tyler glandless pumps to achieve a running life of several years without maintenance or adjustment.

These units are also being developed to pump liquid metals in reactor cooling or heat-exchange systems.



Pump and motor in one shell gives zero leakage

Hayward Tyler & Co Ltd, Luton, Beds.

54 in. gas valves for 700° with no leaks

Of the variety of Blakeborough valves installed at Calder, interest centres principally on the 54 in. diameter power-operated wedge gate valves supplied for the reactor coolant system. These valves are mounted on the hot and cold CO_2 ducts between the pressure-vessels and their associated heat exchangers, and are 32 in number, equally divided between the 'A' and 'B' stations. Half the valves in each case are designed for vertical mounting, and half for horizontal mounting in vertical ducts. They are of outside screw construction, with cast steel casing and gate, monel metal seat and face rings, and aluminium bronze stem and tubular rising spindle. The operating gear is of electric motor driven type, capable of opening or closing the valve in 2¼ minutes. Remote control and remote open-shut indication are provided.

Factors demanding special attention in design and manufacture include the working temperature of 700°F—unusually high for valves of this size; the possible radioactivity of the fluid, necessitating extra precautions against leakage to the surrounding atmosphere; and the very limited periods of access permissible during the operation of the plant, calling for maximum ease and simplicity of maintenance. The exacting nature of the service is reflected in the testing procedure, which included radiographic examination of all pressure castings; hydrostatic tests on casing and gate; seat tests under compressed air; and operating and tightness tests under full working temperature conditions.

Motor driven, the gas valve opens or closes in 2¼ minutes

The requirements of dependable control, with safe operation and accurate seating of the gate from the remote control point, is amply met by the standard Blakeborough motor-gear unit, and involved only minor departures from the firm's regular practice.

Eight 18 in. diameter cast steel wedge gate valves, with direct manual operation and anti-friction features, were supplied for the same conditions; also a considerable number of other types for low pressure services on the conventional or turbo-alternator side of the station.

J. Blakeborough & Sons Ltd, Brighouse, Yorks.

No-glare finish in control rooms

The reactor control rooms for Calder Hall A were supplied by New Western (Engineering) Ltd. The instrumentation required was engineered by The United Kingdom Atomic Energy Authority and the job of the contractors was to present this in a pleasing yet functional form.

New Western, in addition to the provision of the panel, desk and other control room furniture, carried out all instrument erection, both in the control room and on the site, together with the necessary wiring and pipework. They were also entrusted with the testing and commissioning prior to the handing over of the plant to the Operating Authority.

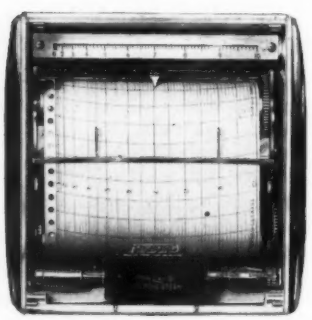
Installed by New Western, Calder's reactor control rooms are fitted with chart recorders by Kent, Elliott and Foxboro-Yoxall

The colour scheme of the room is most interesting and gives a pleasing yet functional appearance. An interesting aspect is the use of New Western non-reflecting finish on the panels. This completely eliminates all reflections, yet does not suffer from the same 'dead' appearance usually associated with matt finishes. The all-over ceiling lighting, together with the colour reflectivity of the floor, was taken into consideration when the choice of the mimic diagram line colours was decided upon. The result of this can be clearly seen in the photograph. Even though this is in black and white the different mimic lines can be clearly seen. Contracts for a further six similar control rooms for Calder Hall B and Chapel Cross have been placed with the same contractors.

New Western (Engineering) Ltd, Meadow Lane, Leeds 11

Pocket size recorders in graphic panel

On the gas circuit graphic panel in the reactor control room, a Foxboro-Yoxall Model 53 *Consotrol* recorder and type 224 receiver integrator, are used to record the gas flow in each circuit. These recorders are very much smaller than the standard instrument and use a chart 4 in. wide. The instruments are pneumatic receivers and all their functions operate within the range 3-15 lb/sq in. thus providing for easy interchangeability. The basic units make available a wide range of indicating, recording and controlling systems to meet any process requirements. The Foxboro receiver integrators consist of two small and simple self-contained units connected only by wires: the flow receiver unit and remote counter which is mounted directly above the chart recorder. The instruments operate directly from a pneumatic flow transmitter and the counter registers up to eight digits.



Part of the mimic panel, the 'Consotrol 53' records gas flow

Foxboro-Yoxall Ltd, Lombard Road, London, S.W.19

Elliott scanning recorders narrow search for burst slugs

For providing a visual presentation of the data coming from the Plessey burst cartridge detection system, eight Elliott 54-point Scanning Recorders, Type ND51, are installed in the reactor control rooms. These were developed from the firm's standard *Elliottronic* recorder, some of which are also used at Calder. The design of this instrument was evolved by the UKAEA and is covered by Patent Application 7126/55. Basically, it is a standard potentiometer recorder receiving signals from the precipitator units. Instead of the single pen, however, the moving carriage carries nine pens and the resistance bridge network is divided with six tapping points so that there are six separate zeros, spaced equally across the chart. The combination of nine pens and six columns gives a total of 54 separate charts which with a width of 1½ in. and a daily travel of the same amount, provides a permanent record of the activity level in the 54 groups of four channels covered by the particular instrument.

Teledeltos electrosensitive paper is used and an alarm is given when any pen fails to print.

Elliott Brothers (London) Ltd, Century Works, London, S.E.13

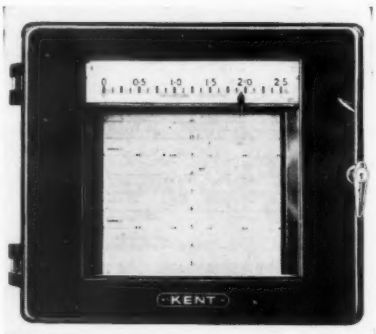
The 'Elliottronic ND51' gives 54 separate records

New Kent recorder chosen for small temperature differences

Instruments supplied by George Kent Ltd include: large numbers of *Multelec* recorders for the measurement and control of radioactivity, reactor power level, pH, conductivity, heat flow and temperature; Kent flow recorders and draught gauges for the measurement of air, steam and gas; and a number of complete control panels.

One instrument of particular interest is the new *Microvolt* recorder. This is used for measuring small temperature differences and consists of a robust electronic amplifier and a standard 0-100 millivolt range *Multelec* recorder. The d.c. potential from, for example, a thermocouple is fed through a filter unit and compared with a reference voltage derived from the 0-100-millivolt-range slidewire through a 1000:1 attenuator. Any difference between these two potentials is passed to a specially designed vibrating-reed synchronous converter which changes the difference into an alternating potential. This is fed into a four-stage resistance-capacity coupler amplifier, rectified, and applied to the *Multelec* galvanometer. The resulting deflection of the galvanometer needle is detected by the clamping bar and scissors mechanism which adjusts the slidewire output until the source potential is balanced.

'Microvolt' recorder plots 1-100 μV potential differences



Potentials of 0-100 microvolts are accurately recorded within fine limits. The instrument can operate with high source resistances, the maximum source resistance depending on the accuracy required and on the range, being 25 kilohms for 100 microvolts full scale. The power sensitivity of this instrument is over a million times greater than that of conventional instruments.

George Kent Ltd, Luton, Beds.

Gammas from ·01-10[13]r/h counted on IDL monitor

Isotope Developments Ltd, as specialists in the industrial and research application of atomic energy, are playing a part in the instrumentation at Calder Hall.

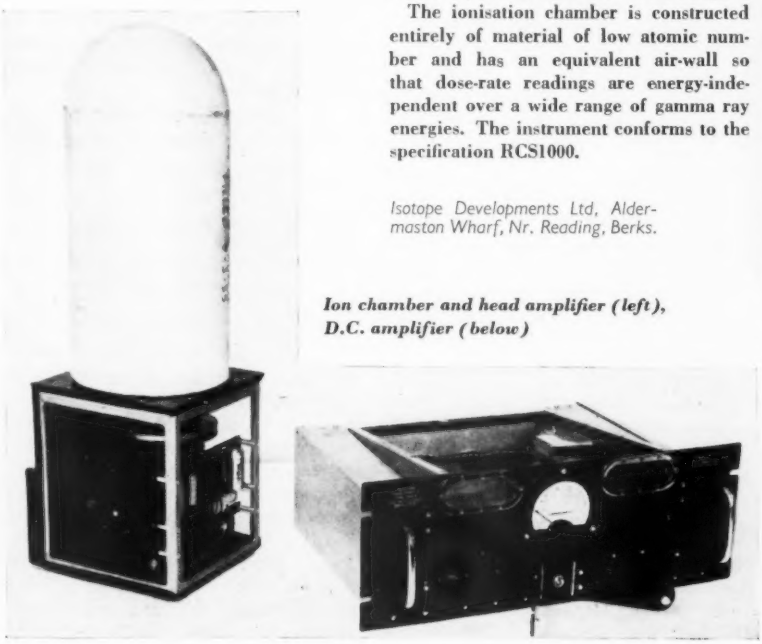
The specific instrument they have supplied is the reactor gamma monitor, type 1457A. This is a mains-operated instrument with a logarithmic scale designed to measure the level of gamma radiation in the vicinity of the reactor. It consists of two main units:—

1 Head amplifier with ionisation chamber.
2 D.C. amplifier with a high level alarm.

The instrument covers the range of 0.01-10[5] Röntgens/hour, the alarm system being adjustable over the whole range.

The ionisation chamber is constructed entirely of material of low atomic number and has an equivalent air-wall so that dose-rate readings are energy-independent over a wide range of gamma ray energies. The instrument conforms to the specification RCS1000.

Isotope Developments Ltd, Aldermaston Wharf, Nr. Reading, Berks.



Ion chamber and head amplifier (left), D.C. amplifier (below)

Essential for dry boxes

Veedip gauntlets

Developed by the firm in collaboration with the AERE, Harwell, Veedip Ltd's rubber gauntlets have been in use for some years for dry-box work in the various establishments of the UKAEA. These gloves are manufactured in high-grade latex rubber and afford the specified degree of protection. They are available in various sizes and thicknesses and are made with either beaded or flanged rims according to the type of dry box.

Veedip Ltd. St. Helens Works, Slough, Bucks.

COMPANIES

Scintillators from Edinburgh

Nuclear Enterprises (GB) Ltd recently completed its new plant at the Sighthill Industrial Estate in Edinburgh, and announces that it is now supplying a complete line of its specialized products and services in scintillation counting to the British, European, and sterling area markets.

The company is a wholly owned associate of Nuclear Enterprises, Ltd of Winnipeg, Canada. The Canadian Company was the first in any country to produce commercial scintillation counters and employ them for geophysical prospecting (1949). The British associate is producing the largest selection of non-crystalline organic scintillators yet offered, including plastic phosphors of all sizes and shapes, loaded liquid scintillators, and scintillating gels for internal counting.

The address is Nuclear Enterprises (GB) Ltd, Bankhead Medway, Sighthill, Edinburgh.

Practical Isotope course

A two-week course was run last month by Isotope Developments Ltd for the firm's agents and associate companies' engineers at their laboratories at Aldermaston, near Reading. As well as British representatives, students came from Austria, France, Germany, Holland and Italy.

During the first week the students were given a full programme on the practical aspects of industrial equipment, laboratory counting and measuring techniques, reactor instrumentation and isotope handling. During the second week, they visited IDL equipment at work at several industrial undertakings.

Mucking out at Dounreay

At the Dounreay site of the AEA's fast reactor, the highly active liquor storage facilities called for the excavation of underground space totalling 20,000 cu yd of rock—mainly sandy Devonian limestone. The spoil was removed by a 33 R.B. excavator shovel size 1¼ cu yd, and a shuttle service of four Muir-Hill 4½ cu yd Gravity Tipping Dumpers. After initial test excavations, output of blasted rock reached 400 cu yd a day or 200 dumper loads on a ten-hour shift. The main contractors are Whatlings Ltd, Glasgow.

Muir-Hill dumpers (Model 10B, 3 cu yd) are also being used for clearing and levelling the site at Aldermaston Court for the AEI-John Thomson MERLIN reactor. The main contractors here are McCarthy, Fitt & Co, Reading, with Collier and Cathey Ltd, Reading, on site clearing.

Fielden's first ten years

This month, Fielden Electronics Ltd, Paton Road, Manchester 22, celebrates the tenth anniversary of its inception. Since October 1946 the company has been transformed from a small concern, manufacturing one electronic instrument for the textile industry, to the still rapidly expanding international organization it is today.

The company was formed in October 1946 by John E. Fielden, MIEE, MSc(Tech) who started with a handful of assistants on the top floor of a building in Holt Town, Ardwick.

In March 1950, the company moved to more extensive premises in Wythenshawe. Two years later, an extension doubling the floor space had to be added to contain the enormously increased volume of work. A further extension, this time covering 9,900 sq ft was added in January 1956, and a block of new offices was added at the same time. At the present time the company employs about three hundred people.

New Pullin headquarters

The Pullin Group of Companies opened new showrooms in London last month. *Electrin House*—as it is known—is in New Cavendish Street W.1 and is a modern six storey building, comprising over 21,000 sq ft of floor space. It provides facilities for the display of a representative range of the products of all companies in the group. In addition, two of the companies, The Pullin Optical Co Ltd, and Stanley Cox Ltd, now have their London sales offices and warehouses on the premises.

Elliott's Nuclear Division

In NUCLEAR POWER'S account of the GEC Simon-Carves research laboratories at Erith in last month's issue (p 222) Elliott Brother's Ltd address was given as Borehamwood, Herts. It is true that part of the reactor simulator was made at the company's Computing Division which is at Borehamwood, but Elliott's Nuclear Division remains at the Century Works, Lewisham, London S.E.13.

NRA Move

Nuclear Research Applications Ltd has transferred its offices from 5 Victoria Street, London, to Emefco House, Bell Street, Reigate, Surrey. (Telephone: Reigate 5341. Telegrams: Nuclear, Reigate, Surrey.)

INSTITUTIONS

Nuclear Education

Many institutions are now running courses in various aspects of nuclear power.

London. Northampton Polytechnic. St John Street E.C.1. *An Introduction to Nuclear Power.* Mondays at 7 pm for 22 lectures commencing October 8. Fee 40s. Details: J. E. Richardson, PhD, BEng, AMIEE, AMIMechE

London. Borough Polytechnic, Borough Road S.E.1. *Nuclear Power.* Thursdays at 4 and 7 pm for 24 lectures commencing October 11. Fee 50s. Details: J. P. Wolfenden, MSc, MIEE

Wolverhampton. Wolverhampton and Staffordshire Technical College, Wulfruna Street. *Introductory Course in Nuclear Engineering.* Friday evenings commencing Oct. 5. Details: Principal.

Bristol. The University. *Nuclear Power Stations.* Thursdays at 2.30 and 5.30 pm commencing October 4 for 25 lectures. Fee 50s. Details: The Department of Adult Education, The University, Bristol 8

Edinburgh. Heriot-Watt College, Chambers Street. *Power Generation by Nuclear Reactors* (advanced course) Saturdays at 9.30 pm for six lectures. Fee 42s. Details: The Secretary

Battelle Institute move

Battelle Institute Ltd have moved to a new address at 24 Ryder Street, London S.W. (Tel: TRAfalgar 1621 Cables: Batinst, Piccy, London).

Ferrite Convention in London

An International Convention on Ferrites is to open in London on October 29 and will last until November 2. Organized by the Institution of Electrical Engineers the Convention will cover: theory, preparation and properties of ferrites; microwave applications; square loop applications; radio and television applications; carrier frequency applications. Some 50 or 60 papers are expected and will be presented and discussed by delegates from France, Germany, Holland and Sweden, USA and, it is hoped, from Russia, as well as from Britain. Dr Willis Jackson, Director of Research at Metropolitan Vickers will introduce the proceedings.

What kind of flux detectors should be used and where should they be placed?

The safety of reactor control schemes

by J. Walker

Continued from page 209, Sept 1956

Control Group, Reactor Division, AERE, Harwell

6. Measurement of nuclear power

Probably the most significant feature of a nuclear reactor as a control problem is the wide range of power involved. It is important to be able to measure this power down to the lowest levels which can exist in the reactor, since it is in the subcritical condition that the reactor has its greatest potential for unexpected divergence. The lower limit of this wide band is set by the spontaneous fission rate of the fuel, other neutron sources, and the lowest mutiplication which can be given to the system.

For example, we may consider BEPO in the shutdown condition with a reactivity of − 2 per cent, i.e. $K_{eff} = 0{\cdot}98$. The reactor contains 4×10^7 grams of natural uranium in which the spontaneous fission rate is about 26 fissions per gram per hour. The energy released at fission is approximately 9×10^{-18} kWh.

Thus the power of the reactor under these conditions will be

$$\frac{26 \times 4 \times 10^7 \times 9 \times 10^{-18}}{(1 - 0{\cdot}98)} \text{ kW} = 0{\cdot}478 \times 10^6 = \tfrac{1}{2} \text{ milliwatt}$$

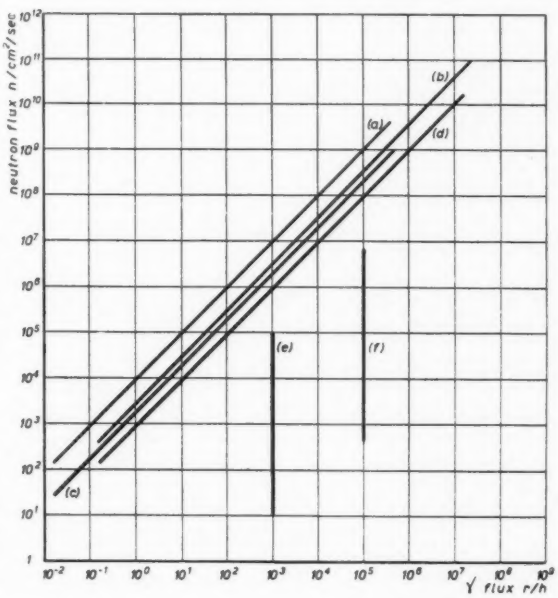
This power is about 10^{-10} of the normal operating power of the reactor. A reduction in neutron flux range can be achieved by the introduction of artificial neutron sources into the reactor. This will be at a small reactivity cost arising from neutron absorption in the source materials. In BEPO, neutron sources of sodium-carbonate/beryllium and some of antimony/beryllium are used, giving a subcritical power increased by a factor 1000 at a cost of about 20×10^{-5} in reactivity.

6.1. Methods of flux detection

The simplest method of neutron flux detection employs a mean-current ionization chamber in which neutrons react with nuclei of boron-10, producing charged lithium nuclei and alpha-particles which cause ionization of the gas in the chamber, which can be collected as a current and suitably amplified. Such an ionization chamber will be sensitive to beta- and gamma-radiation, some of which will arise from activation of the material of the chamber, and some associated with the reactor proper.

The lower limit of usefulness of the device is set by the magnitude of current which can conveniently be measured, and this is in the order of 10^{-12} amps, and the upper limit by the polarizing voltage necessary to ensure complete ion collection. With chambers currently in production, the RC/1, a flux of 80 n/cm²/sec gives the same current as a gamma-field of 1 r/h, at a particular filling pressure. This n/γ sensitivity ratio can be improved by surrounding the chamber by "chemical" lead, 4 inches of which gives an improvement of about a factor 100, the exact value depending on the energy of the gamma-field involved. Equal currents are then produced by 0·8 n/cm²/sec and 1 r/h. and the chamber would not normally be used in fields where the n/γ ratio was not at least 10 times as favourable as this. Under these conditions ranges of 7 or 8 decades are possible, but as we have seen, this is still insufficient. Two sets of chambers may therefore be needed, those used for the lower flux range being retracted when the reactor is at high power to avoid activation of the materials of the chamber.

If the n/γ-ratio is worse than about 10 n/cm²/sec per r/h a pulse counting system may be used instead of the mean current chamber. In such a channel neutrons may be discriminated from gamma by pulse



(a) RC/1 ionization chamber: 500 mg boron, hydrogen at 150 cm Hg

(b) RC/1 ionization chamber: 500 mg boron, hydrogen at 15 cm Hg

(c) RC/1 ionization chamber: 500 mg boron 10, hydrogen at 150 cm Hg

(d) RC/1 ionization chamber: 500 mg boron 10, hydrogen at 15 cm Hg

(e) boron trifluoride proportional counter.

(f) fission chamber: 140 mg uranium 235.

Fig. 5 ***range of use of typical neutron detectors***

THE SAFETY SYSTEM of a nuclear reactor must be designed so that the maximum possible reactivity conceivable under any combination of fault conditions can be removed and the reactor brought sub-critical before any catastrophic situation is reached. This is generally achieved by the primary shut-off system backed by a secondary or safety system.
The importance of power measurement down to the lowest levels is emphasised and factors affecting the design and location of ionization chambers and neutron counters are considered.

LE SYSTEME DE SÉCURITÉ d'un réacteur nucléaire doit être construit d'une manière permettant d'éloigner la réactivité maxima qu'on peut imaginer pour une combinaison quelconque des sources d'avarie ainsi que de ramener le réacteur à la condition sub-critique avant qu'une situation catastrophique soit atteinte. Ceci se fait en général au moyen d'un système primaire d'interruption, aidé par un système secondaire dit de sécurité.
On souligne l'importance de mesurer la puissance jusqu'aux niveaux les plus bas et l'on envisage les facteurs influant sur la construction et l'emplacement des chambres d'ionisation et des compteurs de neutrons.

DAS SICHERHEITSSYSTEM eines Kernreaktors muss so konstruiert werden, dass die denkbar grösstmögliche Reaktivität bei einer beliebigen Kombination von Fehlbetriebfaktoren weggeschafft und der Reaktor in den subkritischen Zustand übergeführt werden kann, bevor eine katastrophale Lage erreicht wird. Dies wird meistens mittels eines primären Ausschaltsystems bewerkstelligt, welches von einem sekundären (Sicherheits-)System unterstützt wird.
Die Wichtigkeit der Leistungsmessung bis zu den niedrigsten Werten wird hervorgehoben, und es werden die für die Konstruktion und Aufstellung der Ionisationskammern und Neutronenzähler wichtigen Faktoren erörtert.

EL SISTEMA DE SEGURIDAD de un reactor nuclear debe diseñarse de forma que sea posible eliminar la máxima radioactividad que pueda concebirse en cualquier conjunto de condiciones defectuosas y hacer al reactor subcrítico antes de que se llegue a una situación catastrófica. Generalmente, ésto es conseguido mediante el sistema primario de cierre, respaldado por otro secundario o de seguridad.
Se subraya la importancia de medir la potencia hasta los niveles más bajos y son considerados los factores que afectan el diseño y emplazamiento de las cámaras de ionización y los contadores de neutrones.

СИСТЕМА БЕЗОПАСНОСТИ ядерного реактора должна быть так спроектирована, чтобы было возможно отвести максимальную мыслимую реактивность при любом сочетании аварийных условий и привести реактор обратно в подкритическое состояние, еще до достижения катастрофического положения. Это достигается обыкновенно посредством первичной системы выключения, которой помагает вторичная система (система безопасности).
Подчеркивается значение замера мощности вплоть до нижайшего уровня; обсуждаются факторы, влияющие на конструкцию и размещение ионизационных камер и счетчиков нейтронов.

height, a limit being set by the resolving time of the equipment. If sufficient gamma-pulses occur within the resolving time they will build-up to a single pulse of sufficient height to be counted as a neutron event. Two types of counters are in use, proportional counters filled with boron-trifluoride suitable up to gamma-levels of about 1000 r/h, and a pulse type ionization chamber coated with fissionable material for gamma-levels of up to between 10 to 100 times this. The disadvantages of the last mentioned is its lower neutron sensitivity and greater cost. The useful range of counting equipment is limited at the lower end by statistical accuracy, and at the upper end by counting losses. Fig. 5 compares the useful ranges of the various forms of neutron flux detector.

From the foregoing, it will be appreciated that for satisfactory control system design, the earliest possible information is required of the expected neutron and gamma flux distributions in the system so that the siting of the flux detectors may be optimised.

7. Siting of flux detectors

A further problem in flux detector siting arises from changes in flux distribution during operation. Possible sources of such change are fuel depletion, temperature change, and the movement of experimental or control absorbers. It must be remembered that the flux detector is essentially measuring a sample of the neutron flux, and the correlation of its signal with a reactor power implies, if not an absolute knowledge of the flux distribution, at least an assumption that the ratio *mean flux/flux at detector* is constant. The designer must therefore see that the flux detectors are reasonably protected from so-called "shadowing" effects, since failure to observe this principle will at best make calibration difficult and at worst might lead to instability in the complete control system.

The shadowing effect of control elements may be demonstrated by reference to BEPO where it is noticeable. Fig. 6 compares the theoretical and practical flux distributions across the reactor in the direction of control rod movement. The ionization chambers observe the flux from the control face of the reactor where the flux is depressed.

A summary of some of the practical aspects of ionization chamber siting is given below:—

1. Chambers should not be sited in a neutron flux exceeding between 3×10^9 and 3×10^{10} n/cm²/sec. The compromise which has to be made here is between radiation damage to the chamber and minimum measurable current.
2. Chambers should be sited in a position of low flux gradient for ease of adjustment and to allow a more uniform flux across the sensitive volume of the chamber.
3. Chambers should not be sited near to gamma-active reactor structures, such as structural steel members. This is merely to meet requirement to keep the n/γ ratio as advantageous as possible.
4. The ionization chamber position should be such as will allow the chamber to view as large a volume of the reactor core as possible. This reduces the tendency to be sensitive to local perturbations of neutron flux; e.g. control rod shadowing.
5. The fullest use of the ionization chamber as a flux detector must be made at all its possible positions. For example, with a retractable chamber care must be taken to ensure that in the retracted position the measurement of flux has not been changed into a measurement of unidirectional neutron current, and that the full sensitive volume is still able to "see" neutrons.
6. Temperature considerations.
   Ionization chambers currently in use will probably operate satisfactorily up to about 100°C, this being the limit set by polythene insulation of the connections.

8. Presentation of flux information

For convenience in operation a logarithmic record of neutron flux is valuable since it condenses the history of the reactor start-up into a form where this is all visible to the operator at once, no intermediate range switching being necessary. Even more significantly, it permits, by straight differentiation of the signal, a means of obtaining a signal proportional to the reciprocal of the reactor period, which is invaluable both as a safety device and also for automatic control.

This form of presentation is achieved by the use of some logarithmic element in the ionization chamber current circuit, classically a diode, though multi-electrode valves are always used to avoid the shift of valve characteristic with cathode temperature.

For a reactor required to work at part loads, a linear presentation of power is important to give the

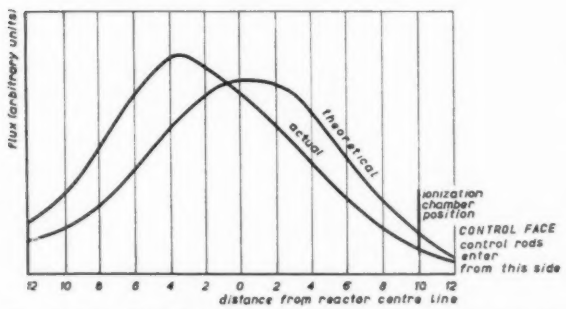

Flux (arbitrary units)
theoretical
actual
ionization chamber position
CONTROL FACE
control rods enter from this side
12 10 8 6 4 2 0 2 4 6 8 10 12
distance from reactor centre line

Fig. 6 ***flux distribution is modified by control rods***

operator a wide scale at the operating point. The wide range is spanned by switching the signal resistors measuring the ionization chamber current. For second-to-second control of the reactor it is convenient to present on a meter the difference between the desired power level and the actual. This again is a feature of interest for automation of the control.

The translation of excess-flux information into control element trip action is the function of special "shut-down" amplifiers. Safety mechanisms are generally arranged to hold their absorber magnetically, release being initiated by an interruption of magnet current. A system is required, therefore, which can measure reactor power and then reduce the magnet current by a large amount for a small increase in flux. Moreover, should the equipment fail, it must announce its inability to operate when called on. A satisfactory way of doing this is to arrange for a failure of the equipment to act in the same way as an excess flux. A number of circuits are available with very high probability of failure to safe, and choice of this circuit has recently received much attention.

These improvements have made reactors safer at the expense of a greater proneness to accidental shut-down due to equipment failure. By using three equipments connected so that simultaneous action of two is required to produce a shut-down, single operation merely giving alarm, the reliability of the system is improved without affecting its safety.

With the above comments on range, siting and presentation in mind, Fig. 7 shows what might be required by way of neutron flux instrumentation in a 100 MW graphite reactor in which sources have been introduced to limit the range to be measured to 8 decades.

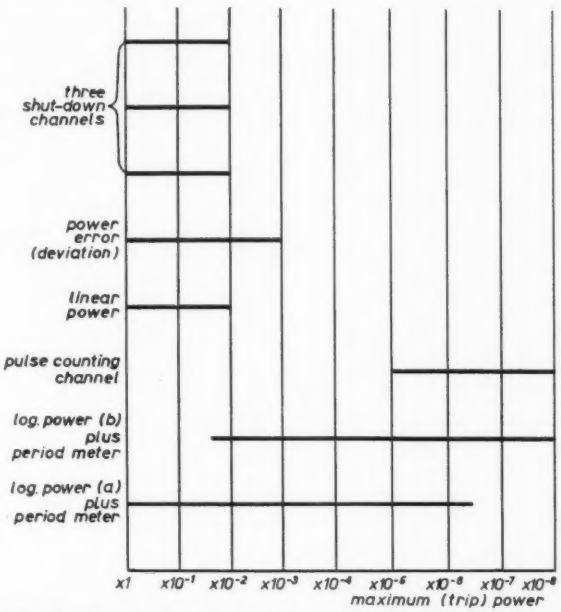

three shut-down channels
power error (deviation)
linear power
pulse counting channel
log. power (b) plus period meter
log. power (a) plus period meter
x1 x10⁻¹ x10⁻² x10⁻³ x10⁻⁴ x10⁻⁵ x10⁻⁶ x10⁻⁷ x10⁻⁸
maximum (trip) power

Fig. 7 ***scheme for the neutron flux instrumentation of a large reactor***

9. Conclusions

The design philosophy outlined above arises from experience essentially with research reactors, the basic idea for this type of reactor being modified to accommodate the problems of other types as these have presented themselves. All the premises for research reactors may not be applicable to single purpose reactors, and it is also probable that different interpretations will be put in different cases on the demarcation between designer's and operator's responsibility for safety. This last problem is a most difficult one which has to be resolved for each reactor built in the light of prevailing circumstances.

10. Acknowledgements

Much of the material printed in this lecture has already been provided in a number of papers read before the Institution of Electrical Engineers and the Institute of Radio Engineers to whom acknowledgements are made.

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Heat recovery from reactors

by P. Chambadal and J. P. Roux

Electricite de France

Continued from page 215, Sept. 1956

In last month's instalment of this article the authors described possible ways of raising steam from a heterogeneous type of reactor: in this they describe how these principles have been applied to the first French power reactors at Marcoule

The G1 installation

G1 is a natural uranium pile moderated by graphite and cooled by air at a pressure only slightly above atmospheric, flowing in an open circuit arrangement. For a power of 40 MW thermal, the air at exit from the pile is under the following conditions:

Mean temperature	220°C
Mass flow	257 kg/s
Heat output	$4{\cdot}75 \times 10^6$ kcal/h

Heat recovery is performed in a single exchanger in which sensible heat only is added to the water. Evaporation to steam is carried out in three flash boilers in series in decreasing order of pressure. These boilers are outside the shield enclosing the hot air circuit. The plant layout is shown in Fig. 8.

Heat Exchanger

The exchanger is of the water-tube counter-current type.

Air side	
Inlet temperature	220°C
Outlet temperature	80°C
Loss of head	300 mm Hg
Mean air speed	6·95 m/s
Water side	
Inlet temperature	60°C
Outlet temperature	220°C
Pressure at entry	20·00 kg/cm²
Pressure drop	4·20 kg/cm²
Velocity	1·18 m/s

The exchanger is constructed in mild steel tubes 21/26 mm. diameter with fins 68 mm. square. The total surface will be about 58,000 m² and the unit was tested to 35 atmospheres.

The tube system comprises 8 identical sections in parallel mounted between entry and exit leaders with valves which permit the isolation of any section should a leak develop. The leaders and valves are outside the shell.

Flash Boilers

		B1	B2	B3
Type		vertical	vertical	horizontal
External diameter	mm	2100	2700	2600
Height	mm	5000	5000	—
Length	mm	—	—	8000
Test pressure	ats	8	4	2
Water flow	kg/s	61,200	55,670	50,990
Steam output	kg/s	5,530	4,680	3,850
Steam pressure	kg/cm²	5,640	1,570	0,318

The Turbo alternator

Manufactured by the Société Rateau, this has a vertical axis and is a single cylinder machine with three admissions and a single exhaust.

The staging is as follows: 6 stages between the first and second admission; 5 between the second and third; 3 after the third.

Since the turbine uses saturated steam the vertical arrangement was proposed by the contractor because it was considered that the moisture from each stage could be more easily removed from annular chambers cast in the stator below each wheel (Fig. 9). Each chamber (Fig. 10) supplies a mixture of steam and

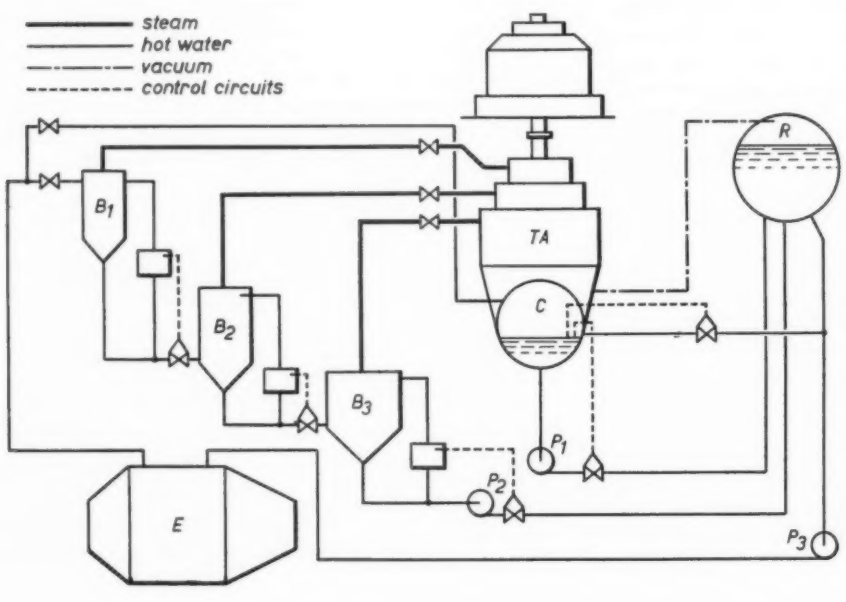

Fig. 8 ***the layout of the G1 steam system. E, reactor heat exchanger. B1, B2 and B3, flash boilers. TA, vertical shaft turbo alternator set. C, condenser. P1, condensate extraction pumps (two off). P2, extraction pumps (two) for flash boiler B3. P3, feed pumps (two off). R, pressurized hot-well tank***

water to a trap which feeds dry steam back to the turbine and discharges the water through an automatic float valve to auxiliary boiler M.P. for stages 1 to 6, to B.P. for stages 7 to 11 and to the condenser for stages 12 and 13. The rest of the installation is of normal construction. The turbine drives a 5,750 kW alternator which generates 5,500 v at 3,000 rev/min. Its efficiency is 96·75 per cent at 0·8 power factor.

The G2 and G3 reactors

These piles are identical and are fuelled with natural uranium moderated by graphite and cooled by carbon dioxide at an average pressure of 15 kg/cm²: they are dual purpose reactors for plutonium and power production.

The gas exit temperatures were defined by the core conditions and had to satisfy two important conditions:

the optimum for the reactor functioning, and
the optimum for the recovery of energy (including power required for the blowers).

These were satisfied by passing the gas through the pile in two different zones.

At the entry side, the central zone is defined by 60 per cent of the core radius and a peripheral zone to the full radius. At exit there is a central zone reaching to 80 per cent of the core radius and peripheral zone.

For a power of 150 MW thermal, the gas conditions will be as follows:

Entry	Central zones	Temperature	70°C
		Flow	414 kg/s
	Peripheral zone	Temperature	150°C
		Flow	400 kg/s
Exit	Central zones	Temperature	291°C
		Flow	625 kg/s
	Peripheral zones	Temperature	335°C
		Flow	162 kg/s

Heat recovery is made in four identical exchangers in which the water is re-heated, evaporated and superheated in two pressure stages each one feeding one admission to the turbine. A fraction of the hot water flow from the low pressure stage is passed to a flash boiler where it is partially evaporated and the steam fed to a low pressure stage in the turbine.

The gas coming from the peripheral zones allows a superheat of the high pressure steam up to 315°C.

The steam pressures have been fixed systematically at a lower level than the gas pressure in order to avoid any possible water leak into the cooling circuit. Fig. 12 shows the plant layout.

Heat exchangers

The exchangers will be built in the form of four vertical towers of the following dimensions:

Diameter	33 m
Height	32 m

They include a low pressure stage with economiser e_1, evaporator V_1, and superheater S_1; a high-pressure evaporator V_2 and a superheater S_2.

The heating and evaporating sections will use tubes with four fins; the superheater tubes will be plain. The exterior diameter is 38 mm.

HEAT FROM A NUCLEAR REACTOR may be used to raise steam either alone or in combination with an external source of fuel heat. In addition, the heat can be supplied either to water or to the steam. Thus, four possible methods of steam raising are possible. A very promising method is that of using nuclear heat only for feed water heating, with a conventionally fired boiler supplying evaporation and superheat. It is shown that this is thermodynamically equivalent to continuous feed heating by bled steam. Another method is by using flash steam boilers in cascade. A description of the power plants of the French G1, G2 and G3 reactors at Marcoule is included.

ON PEUT UTILISER LA CHALEUR des réacteurs nucléaires pour la génération de vapeur sans ou avec une source extérieure de chaleur dérivée d'un combustible. En plus, cette chaleur peut être délivrée à l'eau ou à la vapeur. Donc il existe quatre possibles méthodes de génération de vapeur. La méthode qui paraît promettre de meilleurs résultats est celle où l'on utilise la chaleur nucléaire seulement pour chauffer l'eau d'alimentation, tandis que l'évaporation et le surchauffage se font dans une chaudière normale. On montre que, du point de vue de thermodynamique, ce système est équivalent à celui où l'eau d'alimentation est chauffée d'une manière continue par vapeur épuisée. Une autre méthode est celle employant des bouilleurs en cascade. On décrit les centrales électriques des réacteurs G1, G2 et G3 de Marcoule (France).

KERNREAKTORWÄRME KANN ENTWEDER allein oder zusammen mit einer äusseren Brennstoffwärmequelle zur Dampferzeugung angewandt werden. Ausserdem kann die Wärme entweder dem Wasser oder dem Dampf zugeführt werden. Es gibt somit vier mögliche Dampferzeugungsmethoden. Ein sehr aussichtsreiches Verfahren besteht darin, dass Kernwärme nur zur Speisewasservorwärmung benutzt wird, wobei Verdampfung und Überhitzung in einem üblichen Dampfkessel erfolgen. Es wird gezeigt, dass dieses Verfahren thermodynamisch der kontinuierlichen Speisewasservorwärmung mit Abdampf gleichwertig ist. In einer anderen Methode werden "Flash"-Dampfkessel in Kaskaden angewandt. Zum Schluss werden die Kraftanlagen der französischen Reaktoren G1, G2 und G3 in Marcoule beschrieben.

EL CALOR DE UN REACTOR NUCLEAR puede utilizarse para generar vapor, bien por sí solo o en combinación con una fuente exterior de calor de combustible. Además, el calor puede aplicarse al agua o al vapor. Por lo tanto, existen cuatro métodos posibles de generar vapor. Uno de ellos, muy prometedor, consiste en usar calor nuclear únicamente para caldear el agua de alimentación, con una caldera de atizaje corriente proveyendo evaporación y supercalor. Se demuestra que ésto es equivalente termodinámicamente a un continuo caldeo preliminar por vapor de derivación. Otro método es mediante el uso de calderas de vaporización instantánea en cascada. Es incluída una descripción de las plantas generadoras de los reactores franceses G1, G2 y G3 de Marcoule.

ТЕПЛО, ПОЛУЧАЕМОЕ из ядерного реактора, может использоваться для парогенерации или как единственный источник тепла или в сочетании с другим, наружным источником тепла из обычного топлива. Кроме того тепло может поглощаться водой или паром. Следовательно существуют четыре возможных метода парообразования. Подающий большие надежды метод состоит в том, что ядерное тепло употребляется лишь для подогрева питающей воды, в то время как парообразование и перегрев происходят в котле с обычной топкой. Доказывается, что в термодинамическом отношении этот метод равноценен методу непрерывного подогрева питающей воды отработанным паром. В другом описанном методе применяются каскады «вспышечных» паровых котлов. Описываются также силовые станции французских реакторов G1, G2, и G3 в Маркуль.

This article is based on paper 99 J/2 presented to the 5th World Power Conference in Vienna. *M. Chambadal is Chief of Thermal Research in the Directorate of Electrical Studies and Research: M. Roux is Deputy Director of Nuclear Plant.*

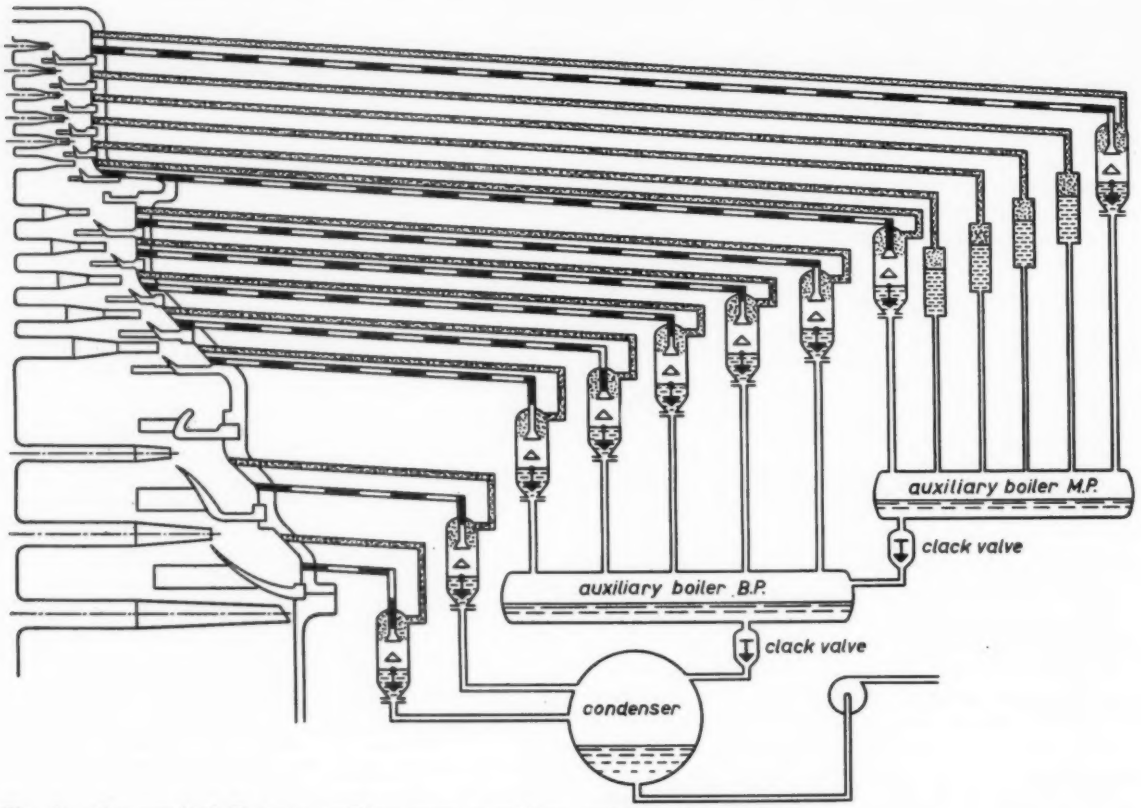

Fig. 9 *the vertical Rateau turbine uses a unique system of continuous steam trapping by means of which the moisture is removed at each stage*

Fig. 10 *the annular moisture collecting channels inside the casing. An interesting method of blade stiffening will be noticed in the last stage*

Fig. 11 *the outside view of the casing shows the three admission belts supplied by three flash boilers*

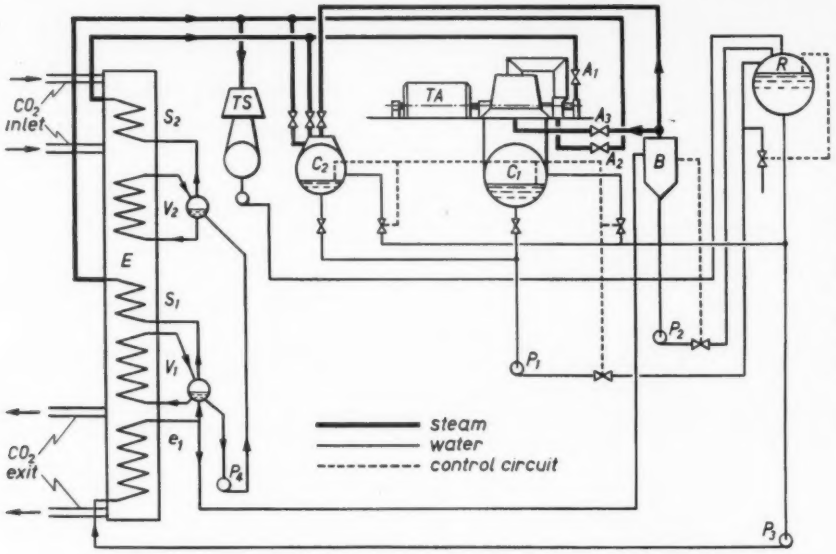

Fig. 12 *the steam circuits to be used for G1 and G2.*
E, main reactor heat exchanger.
B, flash boiler.
TA, turboalternator.
P1, condensate extraction pumps (two off).
P2, extraction pumps for flash boiler (two off).
R, hot-well tank.
P3, feed pumps (two off).
P4, forced circulation pump.
C1, condenser.
C2, dump condenser.
TS, blower turbines (three off)

Thermal characteristics for an output of 150 MW power are as follows:

economiser entry	mass flow	90·80 kg/s
	temperature	38·0°C
economiser exit	temperature	113·0°C
superheater B.P. exit	mass flow	15·62 kg/s
	temperature	169·0°C
	pressure	2·2 kg/cm²
superheater H.P. exit	mass flow	35·67 kg/s
	temperature	315·0°C
	pressure	10·0 kg/cm²

The characteristics of flash boiler B are as follows:

water at entry	flow	39·51 kg/s
	temperature	113·0°C
water at exit	flow	36·62 kg/s
	temperature	75·4°C
steam	flow	2·8 kg/s
	pressure	0·4 kg/cm²

The power turbine gross output with auxiliaries will be about 28,000 kW. It will be supplied with steam from superheaters S_1 and S_2 and also from the flash boiler B. The turbine will be of normal design.

Reactor cooling will be carried out by three turbine driven blowers—one of which will be a stand by unit. The total blowing power required will be about 7 MW. The blower turbines will be fed from superheater B.P. (2·2 kg/cm², 169°C).

A dump condenser will be fitted, able to handle all the steam produced by the exchanger E and boiler B except for that used in the blower turbines. This means that the pile does not have to be shut down when the turbine is taken off: it also permits the turbine to run at a power level below that of the pile (for example if it is started while the pile is already at full power).

Other installations for heat recovery from nuclear reactors are being studied by l'Electricité de France. These later installations are designed principally for the production of electricity while those described in this article have been conceived principally (solely in the case of G_1) for the production of plutonium For this reason economic studies based on these early power plants will be of only doubtful value in a long-term view.

For the future, raising of reactor temperatures may well lead to the adoption of different methods of heat recovery which will make nuclear power more and more attractive economically.

PROGRAMME

Institution of Civil Engineers

Tue Nov 6 London *Presidential Address* by H. J. F. Gourley. 5.30 at the Institution

Institution of Mechanical Engineers

Tue Oct 23 Swansea *Pressurised water reactor for steam power plants* J. M. Kay and F. J. Hutchinson. 6.00 at the Royal Institution of South Wales, Victoria Street

Institution of Electrical Engineers

Tue Oct 9 London *The measurement of radioactivity* Denis Taylor. 5.30 at the Institution

Tue Oct 25 London *Conduction and induction pumps for liquid metals* (BNEC meeting) L. R. Blake. 5.30 at the Institution

Institution of Chemical Engineers

Tue Oct 23 Chester *Fluidisation applied to the handling of bulk solids* D'Arcy Smith. 7.00 at Grosvenor Hotel

Society of Chemical Industry

Fri Oct 12 London *Messel Lecture by Sir Alexander Fleck* 6.30 at the Royal Institution

Wed Oct 17 London *Design of research laboratories* R. Llewelyn Davies. 6.30 at the Institute of Metals, 4 Grosvenor Gardens, SW1

Mon Nov 5 London *Recovery of uranium from low-grade ores* T. V. Arden. 6.30 at 14 Belgrave Square, SW1

Incorporated Plant Engineers

Tue Nov 6 London *Isotopes in industry* C. W. Jones, Isotope Developments Ltd. 7.00 at the Royal Society of Arts

Thu Nov 8 Glasgow *Introduction to atomic energy* J. A. Dixon, Risley. 7.15 at Scottish Building Centre, Sauchiehall Street

Institution of Engineering Designers

Mon Oct 8 Newcastle *Oil seals and packings* E. T. Jagger. 7.15 at 6 Higham Place

RESEARCH REPORTS

*The following reports have recently been made available to the public by the United Kingdom Atomic Energy Authority. They may be borrowed or photo-copies obtained from the following libraries: British Museum; University Library, Cambridge, Radcliffe Science Library: Oxford: National Library of Scotland, Edinburgh: Patent Office Library, London: Science Museum Library, London: Mitchell Library, Glasgow: and the Central Libraries at Birmingham, Liverpool, Manchester, Newcastle-upon-Tyne and Sheffield. Reports marked * may be purchased from Her Majesty's Stationery Office.*

Atomic Energy Research Estabt.

Vacuum equipment for the 4 MeV linear electron accelerator. B. G. Loach. (Mar 10, 1949. 51 pp) 7s 6d. AERE-EL/R 229*

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Selected abstracts of Atomic Energy Project unclassified report literature in the field of radiation chemistry and bibliography of the published literature, papers noted up to March 1956. Pt 2. Organic compounds, including polymerisation reactions. R. W. Clarke. (Mar 1956. 226 pp) 28s 9d. AERE-C/R 1575 (2)*

Interactions between solid and liquid metals and alloys. V. W. Eldred. (Nov 8, 1955. 242 pp) AERE-X/R 1806

The surface energies of solid oxides and carbides. D. T. Livey, P. Murray. (Jan 24, 1956. 31 pp) AERE-M/R 1846

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Preliminary report on shielding economics. E. W. Sidebotham, T. Standen. (Feb 24, 1956. 23 pp) IGE-R 13

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Selected abstracts of atomic energy project unclassified report literature in the field of radiation chemistry and bibliography of the published literature, papers noted up to December, 1955. Pt 1. Theory, interpretations, water and aqueous inorganic systems. R. W. Clarke (Jan 1956. 97 pp) 12s 9d. AERE-C/R 1575 (1)*

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Estimated concentrations of the heavy elements in a liquid metal fuelled reactor with continuous chemical processing. W. H. L. Porter. (June 1956. 43 pp) AERE-M/R 1950

NAMES IN THE NEWS

Mr Airey Neave, *DSO, OBE, MC, Member of Parliament for Abingdon, Berks, has joined John Thompson Limited, Wolverhampton, as their legal adviser.*

Mr Neave's constituency includes the Harwell Atomic Research Establishment and he has a particular interest in atomic energy. He is a frequent speaker on the subject in the House of Commons.

Mr Neave recently relinquished his appointment as parliamentary private secretary to Mr Lennox-Boyd, Colonial Secretary.

Head, Wrightson & Company announce, that with the consent of the Distillers Company, they have appointed Mr George P. Davidson *as head of their Nuclear Power Plant activities. Mr Davidson, who has been Project and Construction Manager with the Engineering division on the Industrial side of the Distillers Company's activities, has wide experience in the construction of large complex chemical plants. He was with DCL for 10 years, and previously with the Shell Refining and Marketing Company and Foster Wheeler, the well-known American boilermakers.*

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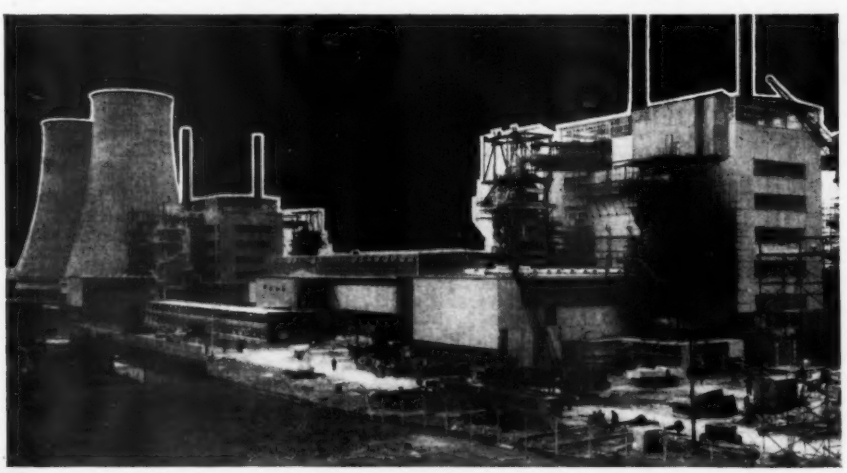

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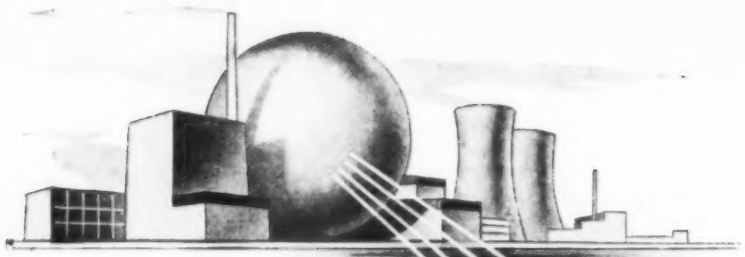

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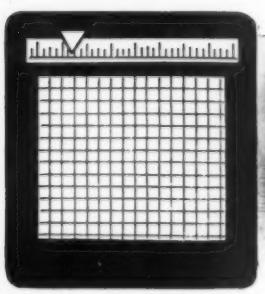

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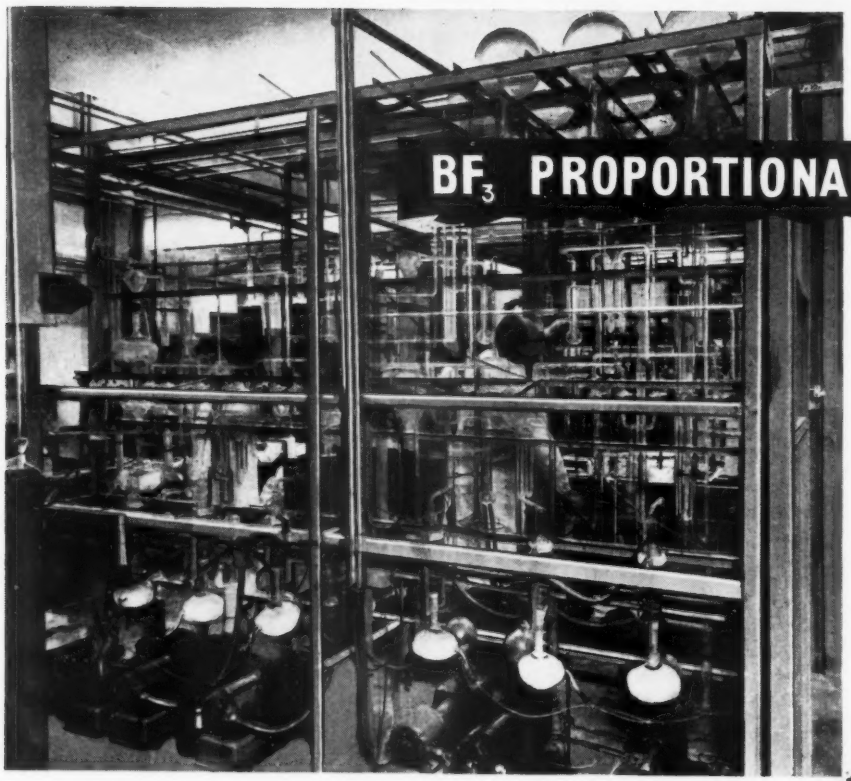

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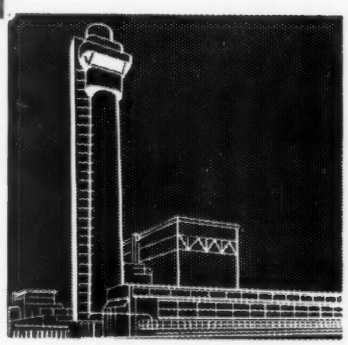

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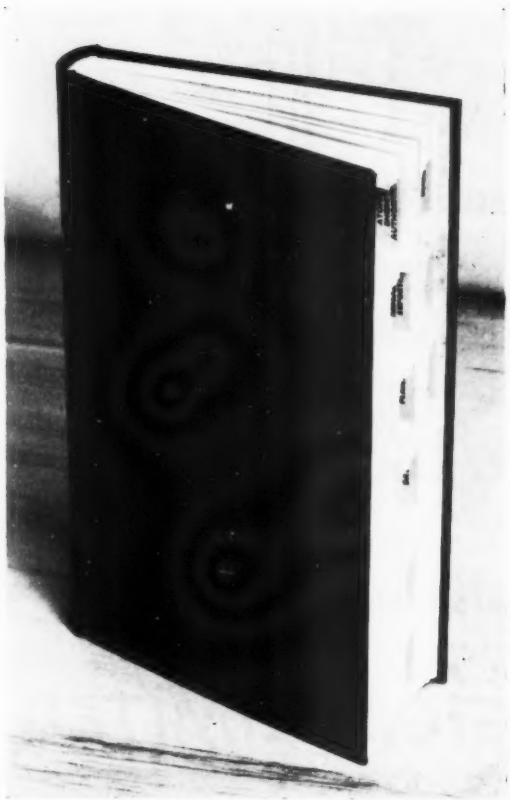

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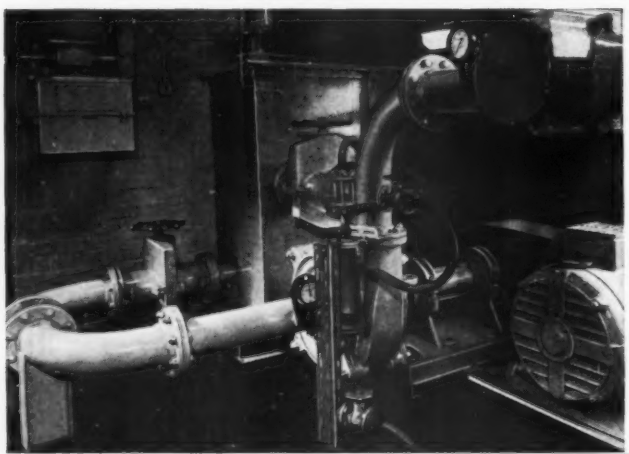

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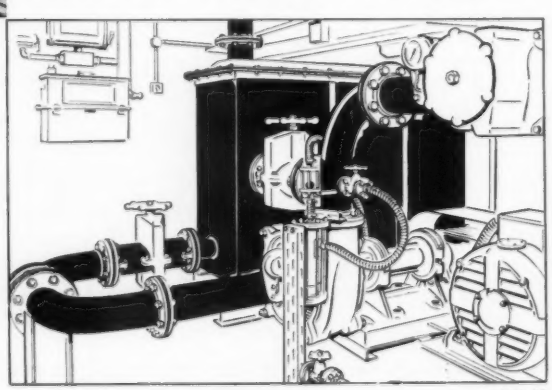

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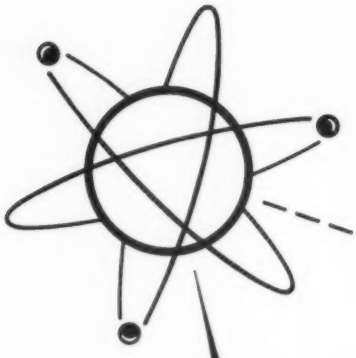

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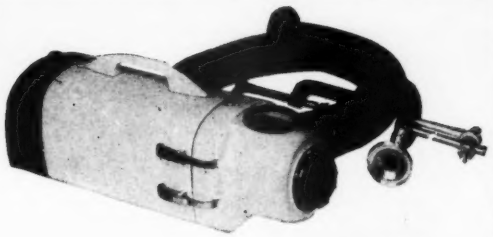

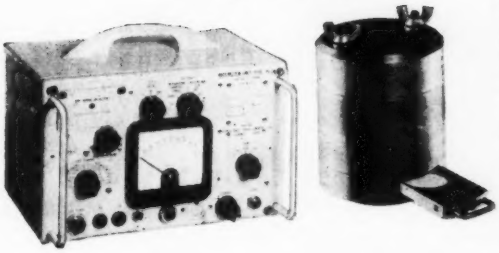

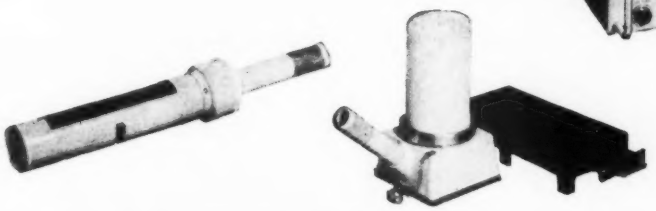

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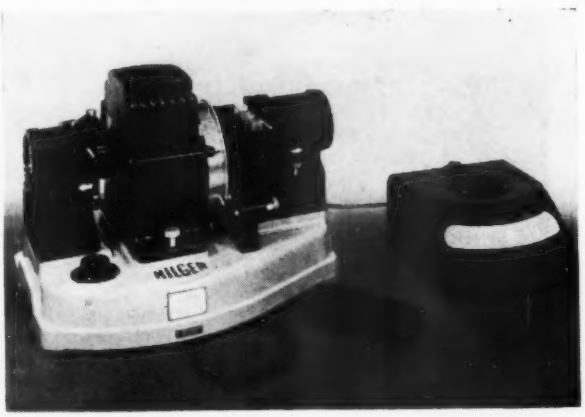

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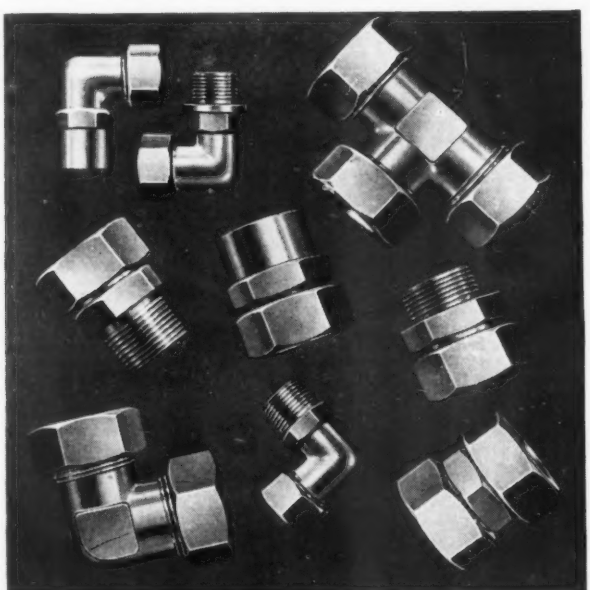

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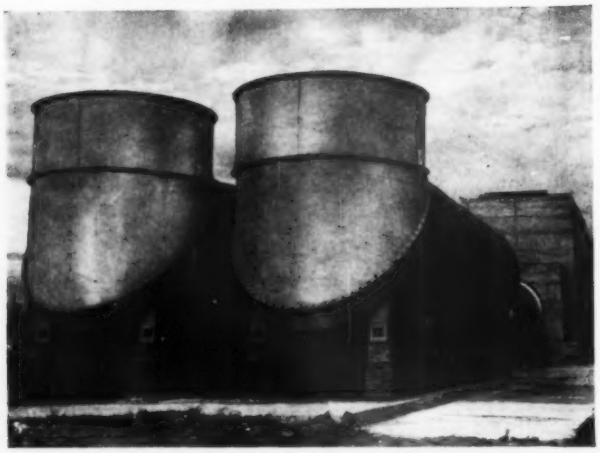

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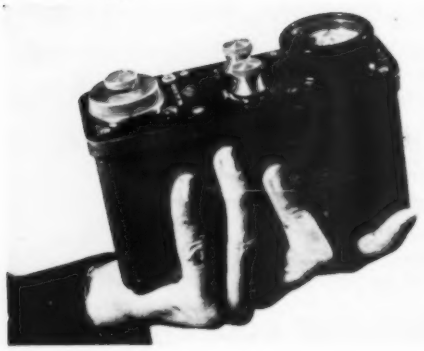

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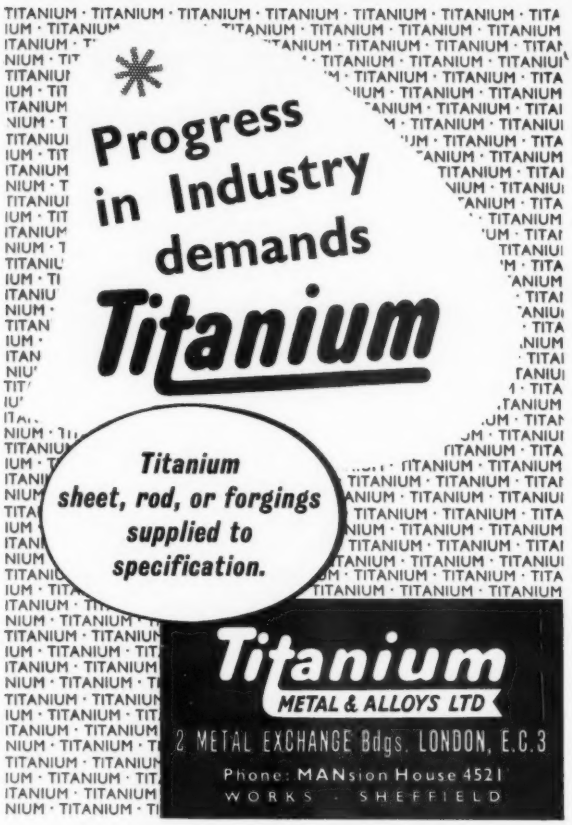

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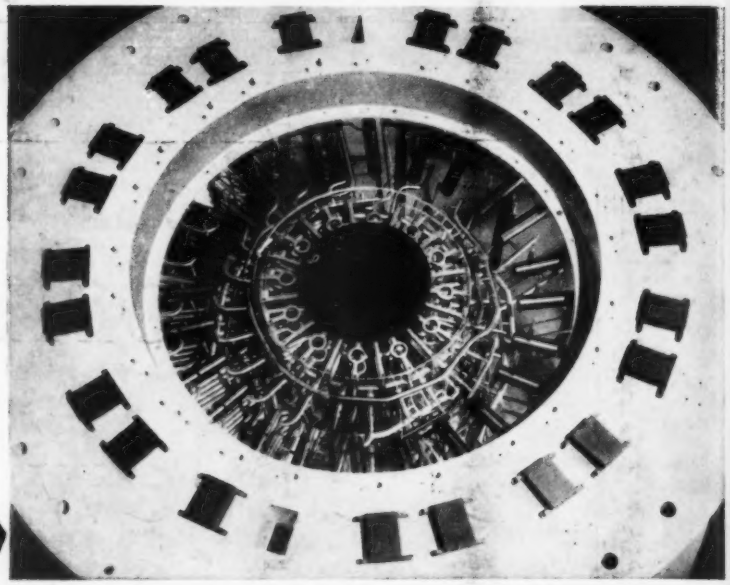
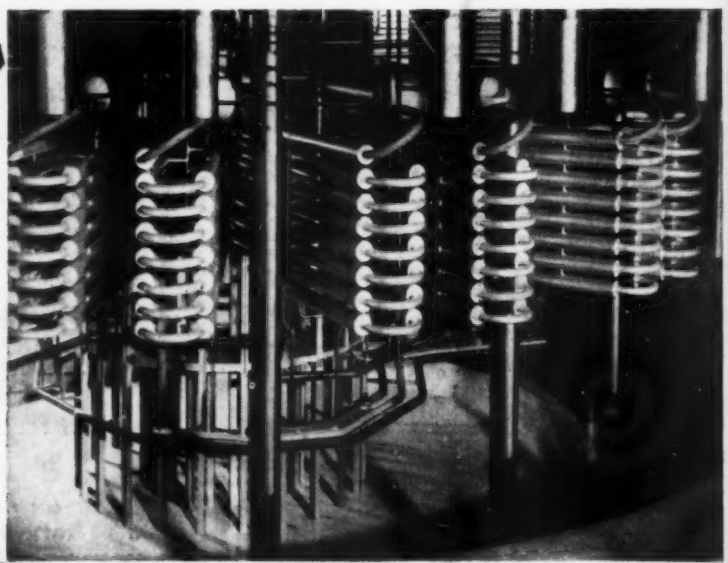
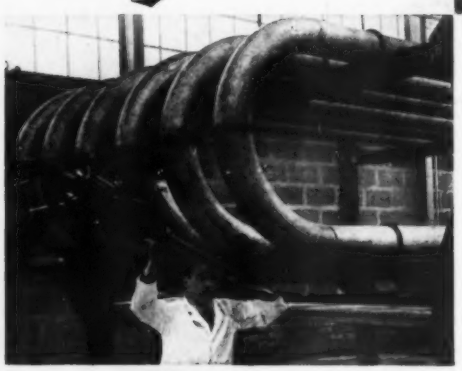


Two views of the accurate scale model of the Dounreay fast reactor showing the arrangement of the primary heat exchanger circuits in relation to the central reactor vessel. The complete primary heat exchange section, in which heat from the reactor is transferred from primary to secondary liquid metal circuits, is enclosed in a concrete biological shield which is here shown partially cut-away



Radiographing welded joints in the actual stainless steel heat exchange units in John Thompson's works. Compare this unit for scale with the illustrations of the model.



The scale model above has been built by John Thompson to aid construction of the U.K. Atomic Energy Authority's fast reactor at Dounreay. John Thompson are manufacturing the stainless steel reactor vessel, all the liquid metal circuits, primary and secondary heat exchangers, ancillary vessels, boiler drums, instrumentation and associated equipment including water treatment plant.

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